Pennsylvania Railroad Company

TEST DEPARTMENT

LOCOMOTIVE TESTING PLANT

AT

ALTOONA, PENNA.

BULLETINS

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1914

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PENNSYLVANIA RAILROAD COMPANY

TEST DEPARTMENT

Locomotive Testing Plant

AT

ALTOONA, PENNA.

TESTS OF AN E2A LOCOMOTIVE

1910

Pennsylvania Railroad Company

LOCOMOTIVE TESTING PLANT

AT

ALTOONA, PENNA.

1910.

TESTS OF "E2A" ATLANTIC TYPE, SIMPLE LOCOMOTIVE.

PENNSYLVANIA RAILROAD COMPANY.

BULLETIN No. 5

The original program of tests that was planned by the Pennsylvania Railroad Company to be made on the Locomotive Testing Plant at St. Louis, in 1904, included tests of one of the Company's simple passenger locomotives of the Atlantic type with D valves* and a locomotive of this type was prepared and held in readiness for the tests, but as the time at St. Louis was not sufficient, these tests could not be carried out.

That tests of a simple two-cylinder passenger locomotive, made under the same conditions as were maintained in the tests of the four-cylinder balanced compound passenger locomotives, would be of particular interest has been apparent.

Upon the completion of the Testing Plant at its permanent location at Altoona this locomotive was placed upon it, and the Pennsylvania Railroad Company now makes public in the following pages the results of such a series of tests as was formerly contemplated.

This locomotive, No. 5266, has been tested by the same methods and under as nearly as possible the same conditions, using the same kind of coal as with the locomotives tested at St. Louis, so that comparisons are possible with these former tests. As the methods used in testing are given in detail in the report of the St. Louis tests, no extended description of them will be given here.

* See "Locomotive Tests and Exhibits," P. R. R., St. Louis, 1904.

Description of the Locomotive.

Locomotive No. 5266 is of the Atlantic type with two simple cylinders and is known as the "E2a" class. It is identical in all respects with the other locomotives of its class and may be taken as representative of a large class of passenger locomotives used on the Pennsylvania Railroad in regular service.

The locomotive was built in 1904 and has seen considerable service since that time. In preparing it for the tests it was taken into the shop and the boiler thoroughly cleaned and new tubes put in. New tires were put on the driving wheels to bring them up to the regular diameter of 80 inches. The machinery was thoroughly overhauled and put in good repair. The cylinders were found to be smooth and they were not rebored. The locomotive was then placed upon the plant and run for some time to get the bearing surfaces in good condition before beginning the tests.

Before the tests were completed the front driving wheel tires had become flat in one place, due, probably, to a soft place in the tire, and the locomotive was removed from the plant and the tires of the driving wheels turned.

The general dimensions of the locomotive are given below:

Total weight, in working order, lbs......	184,167
Weight on drivers, in working order, lbs..	110,001
Cylinders (simple) size inches..........	20½x26
Diameter of driving wheels, inches......	80
Fire-box heating surface, square feet.....	156.86
Heating surface of tubes (water side) square feet	2,471.04
Total heating surface (based on water side tubes), square feet..................	2,627.90
Total heating surface (based on fire side tubes), square feet..................	2,319.26
Grate area, square feet.................	55.5
Boiler pressure, lbs. per square inch......	205
Valves, type..........	Wilson double ported, slide
Valve gear	Stephenson
Fire-box, type..................	Wide, Belpaire
Number of tubes......................	315
Outside diameter of tubes, inches........	2
Length of tubes, inches................	180

The maximum calculated tractive effort at starting is 22,500 pounds with 80 per cent. of the boiler pressure available as mean effective pressure in the cylinders. This is equal to 136.6 pounds per pound of mean effective pressure in the cylinders.

The ratio of weight on drivers to the calculated maximum tractive effort is 4.9 to 1.

General Arrangement of Locomotive.

Figure 918 shows the general arrangement of the locomotive and the location of the instruments used in testing.

Boiler.

The boiler, Figure 920, has no very unusual features; it is of the Belpaire type with a wide grate and sloping back head and throat sheet. The water spaces have been arranged with the idea of promoting good circulation. There is no brick arch, but there is what may be called a combustion chamber, though it is of small volume. This combustion space is increased by the dead grate at the front end of the grate. The feed water is delivered to the boiler through the back head, with an internal pipe to deliver it to the front end. There is no superheater or feed water heating device. The boiler is of steel throughout with plain tubes.

Smoke Box.

The arrangement of the draft appliances and netting in the smoke-box is shown in Figure 921.

The diaphragm is perforated and is fitted with the usual movable lower part. There is an inside stack reaching down nearly to the centre of the smoke-box. The exhaust nozzle is single and the tip is below the centre line of the smoke-box. The steam pipe, or branch pipe, is a single pipe in this locomotive in the centre of the smoke-box.

Neither the diaphragm nor the nozzle was changed during the series of tests.

Grate.

The grate is of the usual rocking finger type (see Figure 922) and can be shaken in four separate sections. At the front end there is a section of the grate without air inlets, or a "dead grate" about 18 inches wide. The grate is practically level. There is a drop grate section at both front and back of the fire-box. The active shaking part of the grate has an area of about 31 square feet, while the total area, including the whole space at the top of the grate up to the boiler sheets, is 55.5 square feet.

Soon after the tests were started it was found that with the damper in the ash-pan open the air inlet was not sufficiently large for tests of heavy load and the inlet area was increased by cutting holes in the ash-pan sides, so that the area of inlet for air was increased from 2.3 square feet to 6.3 square feet. This latter area was found to give not more than seven-tenths of an inch of water vacuum at full load tests.

It is probable that the area of opening in the ash-pan that is required on the Testing Plant, where the locomotive is stationary, is in excess of what would be necessary to give similar draught conditions where the locomotive is in service on the road, though data is not at hand to determine this.

The coal used in the tests of No. 5266 was the Scalp Level coal as used in the tests at St. Louis. The average analyses for the two series of tests are given below:

	St. Louis Tests.	Tests of No. 5266 at Altoona.
Fixed Carbon......	75.85 per cent.	76.25 per cent.
Volatile combustible.	16.25 " "	16.13 " "
Moisture	.9 " "	1.60 " "
Ash	7.00 " "	6.02 " "
	100.00 " "	100.00 " "
Sulphur determined separately	.90 " "	.94 " "
B. T. U. per pound of coal	15025	15143

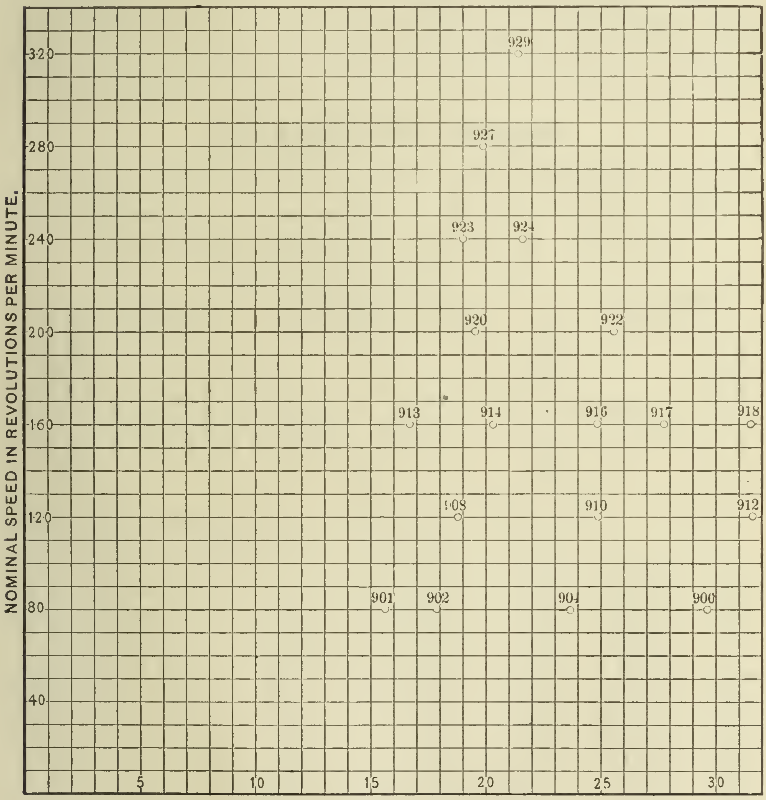
In the following tables and plots the items of most general interest are given, while the complete records of the tests are shown in the appendix.

The conditions under which the tests were made were selected in the following manner: The reverse lever latch was placed in the notch which would give the least possible cut-off in the cylinders, and with fully opened throttle and constant speed a test was run. Then the reverse lever was advanced to the next notch, giving a longer cut-off and another test run. This increase of cut-off was continued until at this speed the boiler would fail to supply steam at approximately working pressure. This process was then repeated for the next higher speed. Thus the tests show the performance of the locomotive for almost its whole range of action. The higher power tests at each speed showing, with certain exceptions, the power that the locomotive is capable

of delivering for a considerable length of time, such as two or three hours or the time required for a run over a 100-mile division of road.

This method of testing the locomotive under conditions which could be sustained for a considerable time, while it is the only fair method, does not, of course, give the much higher power that could be shown for a test of short duration, where the reserve power of a boiler full of heated water is drawn upon for a short time without using the injector to keep up the supply. It will be noted that in all of the tests that the injector was in operation practically all of the time of the test. (See item No. 226 in appendix.)

TESTS ON ATLANTIC TYPE, SIMPLE, LOCOMOTIVE NO. 5266.



CUT-OFF IN PER CENT. OF STROKE.

FIG. 901.

It has been the custom in locomotive tests to obtain a certain fixed evaporation for each square foot of heating surface or a certain quantity of coal burned per square foot of grate surface

before ending the test, so that the total quantities would be approximately equal for tests at either light or heavy power.

While it cannot be said that any fixed method was rigidly adhered to in these tests, an endeavor was made to obtain an evaporation of 30 pounds of water for each square foot of heating surface or a total of approximately 70,000 pounds, though no tests were made of more than three hours duration. At speeds of 240 and 280 revolutions per minute many difficulties arise that limit the possibility of making successful tests, so rather than incur the risk of having to stop the locomotive with a test uncompleted, the time of these high speed tests was reduced to an hour or an hour and a half. As data throughout the full range of the boiler capacity can be determined at the intermediate speeds, there is little gained by running these high speed tests longer than is required to obtain enough readings to determine the performance of the engines of the locomotive and the draw-bar pull.

BOILER PERFORMANCE

General Conditions—Table No. 901.

The data for the tests in tables 901 to 908 inclusive are

TABLE No. 901—GENERAL BOILER CONDITIONS.

Identification of Test		Duration of Test, Minutes	Average Pressure Lbs. Per Sq. Inch		Av. Temp. Degrees F.		Total Coal Fired Per Sq. Ft. of Grate, Lbs.
Test Number	Laboratory Designation		Boiler Pressure	Atmospheric Pressure	Testing Plant	Feed Water	
		(Cal)	(217)	(221)	(208)	(211)	(Cal)
901	80-15-F	180	201.3	14.06	61.0	48.0	92.5
902	80-20-F	180	200.1	14.16	64.0	46.4	105.8
904	80-25-F	180	198.5	14.19	65.0	48.0	118.9
908	120-20-F	180	201.0	14.06	69.3	48.5	134.1
913	160-15-F	180	198.0	14.24	60.0	45.2	151.6
914	160-20-F	180	202.9	14.30	55.5	43.7	166.6
906	80-30-F	180	202.6	14.15	59.0	40.0	160.3
910	120-25-F	180	200.5	14.12	61.8	47.6	182.2
920	200-20-F	150	202.0	14.12	53.0	42.6	171.1
916	160-25-F	150	200.0	14.37	46.5	42.2	195.5
923	240-15-F	90	196.4	13.97	60.5	40.8	138.8
912	120-30-F	150	202.7	14.10	64.0	42.2	182.1
917	160-27-F	180	188.4	14.15	60.0	46.8	262.3
924	240-20-F	60	197.5	14.04	61.0	40.5	111.2
927	280-15-F	60	194.4	14.03	51.5	41.0	91.3
922	200-25-F	72	202.1	14.30	54.0	41.8	109.2
918	160-30-F	60	186.1	14.11	61.5	50.1	101.6

arranged according to the equivalent evaporation per hour (item 344, table No. 902), as this is a convenient index of the rate at which the boiler is working. The average steam pressure (item 217) can best be studied by reference to the graphical logs of the tests where the variations in pressure at each 10-minute interval are shown. The pressure reading was obtained by means of a sensitive gage mounted near the locomotive and connected to it by a flexible pipe. The gage has been found to give better service in this position than when mounted on the locomotive and exposed to the heat of the boiler. A correction was made in the gage reading for the head of condensed steam in the gage connection pipe.

As indicated in column 211, the feed water temperature was, at times, as low as 40° F, making a difference between the actual weight of water evaporated per hour and the equivalent evaporation of as much as 4,983 pounds.

The last column of table 901 gives the total coal per square foot of grate for the whole time of the test. In two tests only, the quantity is below 100 pounds.

Evaporation—Table 902.

This table shows the rates at which the boiler delivered steam to the engines, and it also shows the range of this delivery and the practical limitations upon the boiler capacity. Starting with an evaporation of 14,673 pounds per hour, the rates per hour advance by fairly even stages until an evaporation of about 30,000 pounds is reached. Where an evaporation of 30,721 pounds per hour is shown in test 918 the steam pressure, as shown by the graphical log for this test, could not be maintained and the upper limit of boiler delivery was exceeded in this test. The boiler may be expected to deliver a maximum of 30,000 pounds of steam per hour with this coal and these draught arrangements. The quality of the steam does not vary greatly from a mean of about 98.5 per cent., or practically dry steam, and the results do not indicate that a greater amount of moisture is present in the steam when the boiler is delivering large quantities of steam than when the evaporation is low.

TABLE No. 902—EVAPORATION.

Identification of Test		Duration of Test, Minutes	Water and Steam		Calorimeter Results			Equivalent Evaporation, Lbs. Per Hour
Test Number	Laboratory Designation		Total Lbs. Evaporated	Pounds Evaporated Per Hour	Quality Steam in Dome	Quality Steam in Branch Fipe	Degrees Superheat Branch Pipe	
		(Cal)	(264)	(340)	(228)	(229)	(230)	(344)
901	80-15-F	180	44020	14673	.9856	.9983	0	17806
902	80-20-F	180	48226	16075	.9866	.9997	0	19546
904	80-25-F	180	55536	18512	.9860	1.0022	4.00	22466
908	120-20-F	180	60406	20135	.9860	1.0024	4.20	24434
913	160-15-F	180	62276	20759	.9864	1.0055	9.60	25259
914	160-20-F	180	66120	22040	.9854	1.0067	11.72	26851
906	80-30-F	180	67608	22536	.9845	.9994	0	27519
910	120-25-F	180	70001	23334	.9860	1.0069	12.08	28330
920	200-20-F	150	65283	26113	.9856	1.0098	17.16	31841
916	160-25-F	150	66090	26436	.9859	1.0106	18.57	32246
923	240-15-F	90	41048	27365	.9850	1.0091	15.93	33383
912	120-30-F	150	69273	27711	.9851	1.0071	12.43	33792
917	160-27-F	180	86010	28670	.9860	1.0202	35.51	34793
924	240-20-F	60	28670	28670	.9860	1.0093	16.29	35014
927	280-15-F	60	28890	28890	.9854	1.0084	14.73	35240
922	200-25-F	72	36360	30300	.9859	1.0127	22.23	36981
918	160-30-F	60	30721	30721	.9860	1.0218	38.38	37170

Boiler Power—Table 903.

The boiler horse-power (item 349) is based upon the generally accepted unit of an equivalent evaporation of 34.5 pounds of water per hour for each boiler horse-power. The range of the tests is from about 500 to 1,000 boiler horse-power. This table shows that the boiler will deliver about 1,000 boiler horse-power, which is at the rate of about .43 of a horse-power per square foot of heating surface, or 2.32 square feet of heating surface per horse-power. There is about 18 horse-power delivered per square foot of grate surface.

TABLE No. 903—BOILER POWER.

Identification of Test		Duration of Test, Minutes	Equivalent Evaporation, Lbs.		Boiler Horse-Power		
Test Number	Laboratory Designation		Per Sq. Ft. of Grate Surface Per Hour	Per Sq. Ft. of Heating Surface Per Hour	Total	Per Sq. Ft. Heating Surface	Per Sq. Ft. Grate Surface
		(Cal)	(Cal)	(345)	(349)	(Cal)	(Cal)
901	80-15-F	180	321	7.68	516.0	.222	9.30
902	80-20-F	180	352	8.43	566.6	.244	10.21
904	80-25-F	180	405	9.69	651.1	.281	11.73
908	120-20-F	180	440	10.54	708.2	.305	12.76
913	160-15-F	180	455	10.89	732.1	.316	13.19
914	160-20-F	180	484	11.58	778.3	.336	14.02
906	80-30-F	180	496	11.87	797.7	.344	14.37
910	120-25-F	180	510	12.21	821.2	.354	14.80
920	200-20-F	150	574	13.73	922.9	.398	16.63
916	160-25-F	150	581	13.90	934.7	.403	16.84
923	240-15-F	90	602	14.39	967.6	.417	17.43
912	120-30-F	150	609	14.68	979.4	.422	17.65
917	160-27-F	180	627	15.00	1008.5	.435	18.17
924	240-20-F	60	631	15.10	1014.9	.438	18.29
927	280-15-F	60	635	15.19	1021.4	.440	18.40
922	200-25-F	72	666	15.94	1071.9	.462	19.31
918	160-30-F	60	670	16.03	1077.4	.465	19.41

Coal and Rate of Combustion—Table 904.

The coal fired per hour ranges from 1,665 to 6,101, but it does not follow exactly the increase in evaporation. This can be accounted for principally as due to variation in estimating the depth of fire at the beginning and end of the test, and the inconsistencies are most marked in the tests of short duration. From observation and as indicated on the graphical logs, the rate of firing was as uniform as can be expected.

TABLE No. 904—COAL AND RATE OF COMBUSTION.

Identification of Test				Fuel In Pounds			Rate of Combustion	
Test Number	Laboratory Designation	Duration of Test, Minutes	Total Dry Coal Fired	Total Combustible By Analysis	Dry Coal Fired Per Hour	Combustible Fired Per Hour	Dry Coal Fired Per Sq. Ft. of Grate Per Hour	Dry Coal Per Sq. Ft. Heating Surface Per Hour
		(Cal)	(235)	(236)	(338)	(Cal)	(339)	(Cal)
901	80-15-F	180	4994	4723	1665	1574	30.00	.718
902	80-20-F	180	5802	5392	1934	1797	34.85	.834
904	80-25-F	180	6530	6140	2177	2047	39.23	.939
908	120-20-F	180	7365	6926	2455	2309	44.24	1.059
913	160-15-F	180	8186	7742	2729	2581	49.17	1.177
914	160-20-F	180	8995	8508	2998	2836	54.01	1.293
906	80-30-F	180	8797	8212	2932	2737	52.83	1.264
910	120-25-F	180	10000	9410	3333	3137	60.04	1.437
920	200-20-F	150	9235	8735	3694	3494	66.56	1.593
916	160-25-F	150	10552	9981	4221	3992	76.05	1.820
923	240-15-F	90	7620	7113	5080	4742	91.53	2.190
912	120-30-F	150	9970	9335	3988	3734	71.86	1.720
917	160-27-F	180	14405	13547	4802	4516	86.53	2.070
924	240-20-F	60	6101	5695	6101	5695	109.93	2.631
927	280-15-F	60	5012	4678	5012	4678	90.31	2.161
922	200-25-F	72	5980	5599	4983	4666	89.78	2.149
918	160-30-F	60	5581	5249	5581	5249	100.58	2.406

Cinders and Sparks—Table 905.

As the coal used in these tests was of a friable nature and as much of it was of very small size when fired, it is to be expected that the quantities of cinders and sparks will be large. In test 918, laboratory designation 160—30—F, the cinders caught in the smoke-box were 987 pounds, and this quantity was sufficient to fill the smoke-box, which is not of the self-cleaning design, so that the draft was obstructed and the boiler failure, which occurred in this test, is directly traceable to this cause.

The calorific value of the cinders and sparks is high. They represent practically unburned coal, and in view of the large quantities drawn through the tubes it is apparent that better results could be expected from burning this quantity of coal on a much larger grate where the draft action need not be so intense in order to burn the quantity of fuel required.

TABLE No. 905—CINDERS AND SPARKS.

Identification of Test		Duration of Test, Minutes	Total in Lbs. Per Hour			Calorific Value B. T. U. Per Lb.	
Test Number	Laboratory Designation		Cinders in Smoke-Box	Sparks from Stack	Cinders and Sparks	of Cinders	of Sparks
		(Cal)	(238)	(239)	(240)	(250)	(251)
901	80-15-F	180	52	16	68	11713	10868
902	80-20-F	180	46	10	56	10370	11784
904	80-25-F	180	82	16	98	12491	11784
908	120-20-F	180	101	23	124	10606	8484
913	160-15-F	180	98	43	141	12770	8910
914	160-20-F	180	194	47	241	11048	9860
906	80-30-F	180	66	47	113	11291	10065
910	120-25-F	180	236	15	251	11194	11017
920	200-20-F	150	204	85	289	9471	11378
916	160-25-F	150	302	128	430	9287	9042
923	240-15-F	90	508	84	592	10506	9299
912	120-30-F	150	110	153	263	11998	12057
917	160-27-F	180	492	140	632	9701	11617
924	240-20-F	60	514	95	609	12157	11977
927	280-15-F	60	584	58	642	11472	12197
922	200-25-F	72	316	208	524	11523	11198
918	160-30-F	60	987	238	1225	11497	10899

Draught and Rate of Combustion.

Smoke-Box and Fire-Box Temperatures—Table No. 906.

In this table are shown the results of the observations of the draught, and in Fig. 902 these draught results are plotted in connection with the amounts of coal burned. The figures show wide variations, and this is to be expected, as the draught is influenced by a number of factors, such as the thickness of the fire, the boiler pressure and by the position of the fire door. The readings are the average of readings taken at the beginning of each ten-minute interval without regard to whether the fire door was

TABLE No. 906—DRAUGHT, RATE OF COMBUSTION, SMOKE-BOX AND FIRE-BOX TEMPERTURES.

Identification of Test		Duration of Test, Minutes	Draught in Inches of Water				Temp. Degrees F.		Dry Coal Per Sq. Ft. Grate Surface, Per Hour, Lbs.
Test Number	Laboratory Designation		In Front of Diaphragm	Back of Diaphragm	In Fire-Box	In Ash-Pan	In Fire-Box	In Smoke-Box	
		(Cal)	(222)	(223)	(224)	(225)	(212)	(207)	(339)
901	80-15-F	180	2.0	1.8	.6	.2	1774	562	30.00
902	80-20-F	180	2.1	1.9	.8	.1	1918	579	34.85
904	120-20-F	180	3.3	3.1	1.4	.7	1803	618	39.23
908	160-15-F	180	3.9	3.4	1.7	.7	1859	644	44.24
914	160-20-F	180	3.1	2.8	.9	.2	2078	633	49.17
906	80-30-F	180	3.7	3.2	1.2	.2	1952	654	54.01
910	120-25-F	180	3.4	2.9	.7	.3	1915	630	52.83
920	200-20-F	180	5.1	4.5	2.3	1.0	1965	672	60.04
916	160-25-F	150	5.0	4.2	1.3	.2	2076	679	66.56
923	80-25-F	150	5.2	4.4	1.5	.3	1935	681	76.05
912	240-15-F	90	5.6	4.7	1.3	.2	2025	693	91.53
924	120-30-F	150	4.9	4.2	1.4	.3	2077	665	71.86
927	160-27-F	180	7.7	6.2	2.1	.3	2058	719	86.53
922	240-20-F	60	5.4	4.6	1.4	.3	2266	675	109.93
918	280-15-F	60	5.6	4.9	1.5	.2	2165	715	90.31
917	200-25-F	72	6.0	5.1	1.6	.3	2180	694	89.78
913	160-30-F	60	8.9	8.0	3.0	1.3	2143	740	100.58

open or not. As a matter of fact, in some of the heavier power tests the fire door is open more than one-half of the time, and as this is one of the fixed conditions governing the intensity of the draught, it has not been eliminated from the readings of the average draught.

Fire-box and smoke-box temperatures were measured by means of thermo couples.

Evaporative Performance—Table 907.

In Figure No. 905 the equivalent evaporation is plotted with the evaporation per square foot of heating surface. The equiva-

TABLE No. 907—EVAPORATIVE PERFORMANCE.

Identification of Test		Duration of Test, Minutes	Evaporative Performance			B. T. U. Per Pound of Dry Coal	Efficiency of Boiler
Test Number	Laboratory Designation		Total Water Divided by Total Coal	Equivalent Evaporation Per Pound of Dry Coal	Equivalent Evaporation Per Pound of Combustible		
		(Cal)	(Cal)	(347)	(348)	(248)	(350)
901	80-15-F	180	8.57	10.69	11.31	15264	67.65
902	80-20-F	180	8.21	10.11	10.88	15077	64.76
904	80-25-F	180	8.42	10.32	10.98	15167	65.71
908	120-20-F	180	8.12	9.95	10.58	15167	63.36
913	160-15-F	180	7.40	9.26	9.79	15264	58.59
914	160-20-F	180	7.15	8.96	9.46	15264	56.68
906	80-30-F	180	7.60	9.39	10.05	15020	60.38
910	120-25-F	180	6.92	8.50	9.03	15167	54.13
920	200-20-F	150	6.88	8.62	9.11	15264	54.52
916	160-25-F	150	6.09	7.64	8.08	15264	48.34
923	240-15-F	90	5.33	6.57	7.04	15020	42.25
912	120-30-F	150	6.85	8.47	9.05	15057	54.32
917	160-27-F	180	5.91	7.25	7.70	15167	46.17
924	240-20-F	60	4.65	5.74	5.15	15020	36.91
927	280-15-F	60	5.70	7.03	7.53	15020	45.20
922	200-25-F	72	6.00	7.42	7.93	15057	47.59
918	160-30-F	60	5.45	6.66	7.08	15167	42.41

lent evaporation per pound of coal ranges from 10.69—which is obtained at the lowest rate of evaporation, viz: 7.68 pounds per square foot of heating surface— to a minimum of 5.74. The highest rate of evaporation was 16.09 pounds per square foot of heating surface.

From the results in this table it is evident that the economical performance of the locomotive boiler is very creditable when compared with results obtained from stationary boilers. The rates of coal burning and evaporation for the locomotive begin at and extend beyond the maximum of the ordinary stationary boiler.

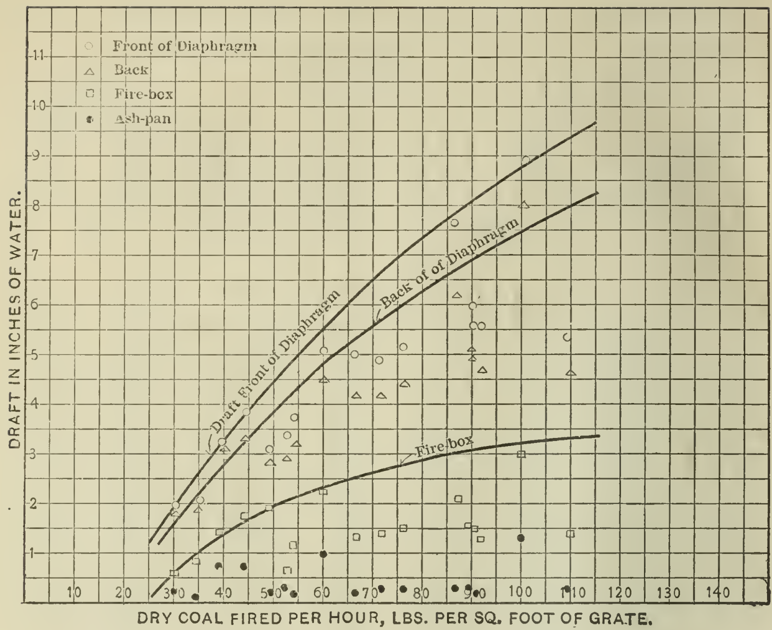


FIG. 902—DRAFT AND RATE OF COMBUSTION.

As shown in column 248, the calorific value of the dry coal in B. T. U.'s is very uniform for all of the tests. The determinations of heating value were made from samples taken from each car of coal used. These samples were taken from the coal conveyor as the coal was being placed in the testing plant coal bins.

The efficiency of the boiler, as given in column 350, is based upon the calorific value of the dry coal.

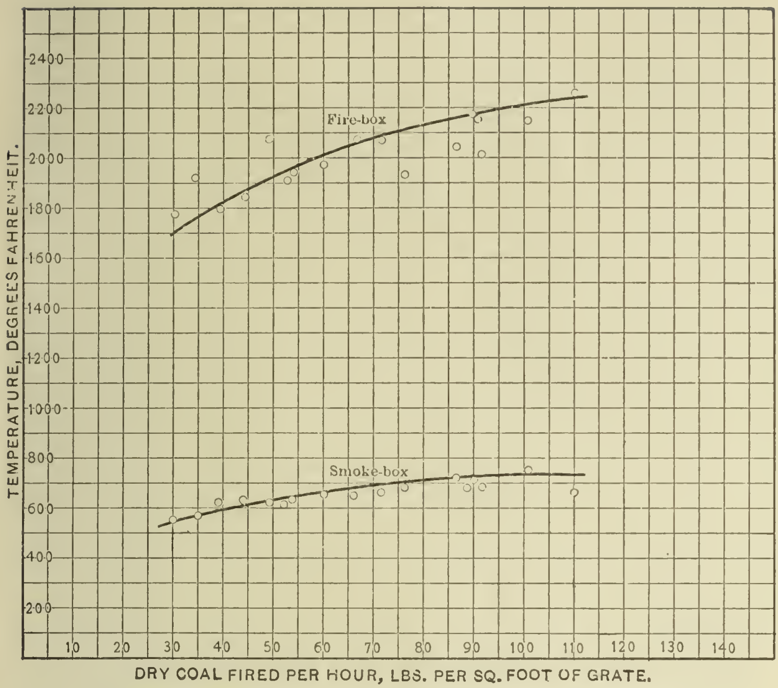


FIG. 903—FIRE-BOX AND SMOKE-BOX TEMPERATURES.

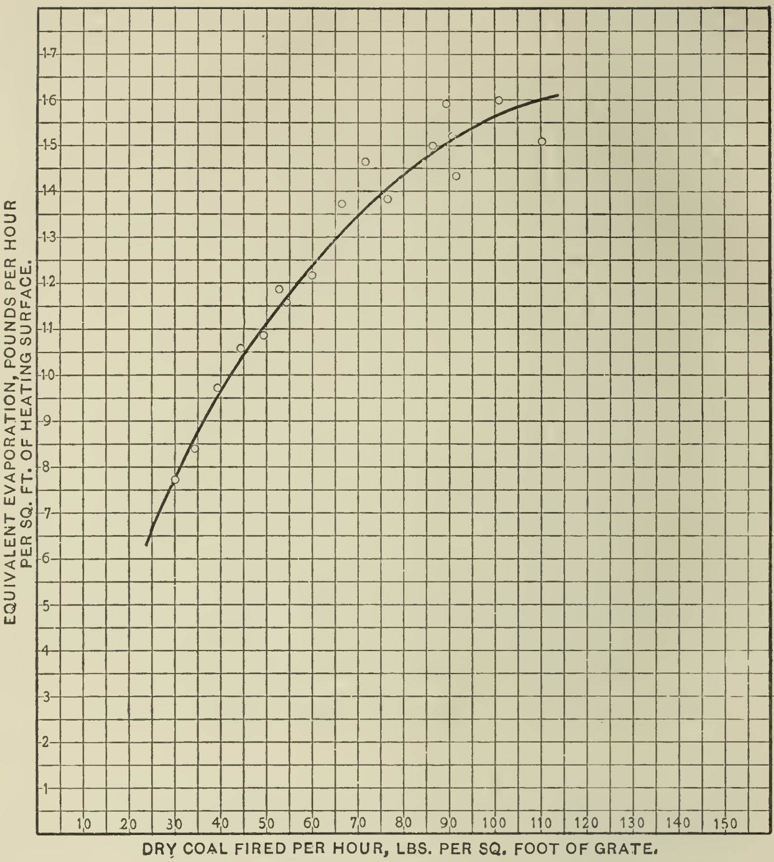


FIG 904—RATE OF COMBUSTION AND RATE OF EVAPORATION.

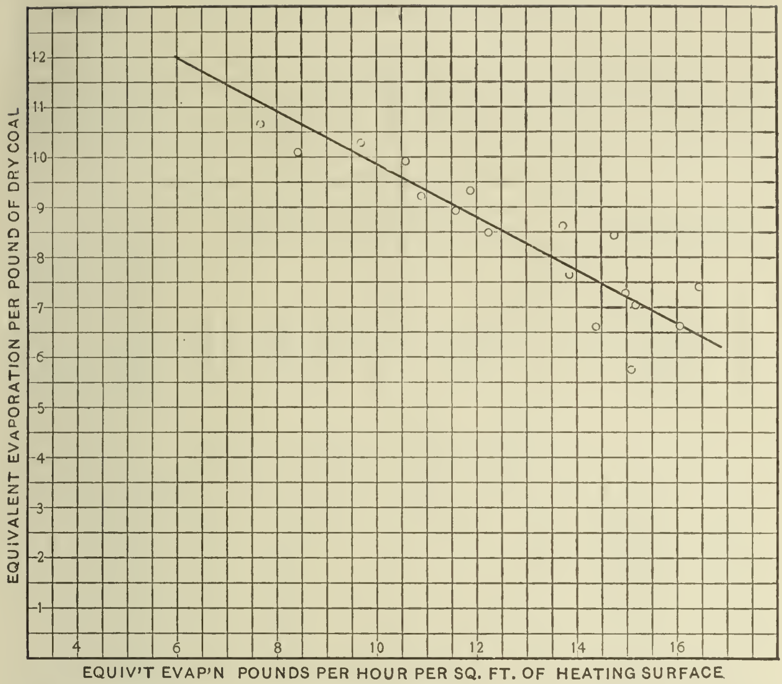


FIG. 905—RATE OF EVAPORATION AND EVAPORATION PER LB. OF COAL.

SMOKE-BOX GASES—TABLE 908.

The analysis of the smoke-box gases is of interest in showing the completeness of the combustion, and by reference to column 254 a very small percentage of carbon monoxide is shown

TABLE No. 908—SMOKE-BOX GASES.

Identification of Test		Duration of Test, Minutes	Analysis of Smoke-Box Gases				Calorific Value Coal as Fired	Per Cent. of Heat in Coal, Lost by Presence of CO
Test Number	Laboratory Designation		Per Cent. Oxygen O	Per Cent. Carbon Monoxide CO	Per Cent. Carbon Dioxide CO2	Per Cent. Nitrogen N		
		(Cal)	(253)	(254)	(255)	(256)	(Cal)	(Cal)
901	80-15-F	180	9.26	0	10.46	80.26	14849	0
902	80-20-F	180	8.40	0	10.67	80.93	14896	0
904	80-25-F	180	11.80	0	7.80	80.30	15009	0
908	120-20-F	180	8.70	0	10.50	80.80	15009	0
913	160-15-F	180	6.86	.13	12.20	80.80	14849	0.61
914	160-20-F	180	10.30	0	9.06	80.60	14849	0
906	80-30-F	180	8.53	0	9.67	81.80	14853	0
910	120-25-F	180	5.40	0	13.60	80.90	15009	0
920	200-20-F	150	9.13	.06	10.33	80.46	14849	0.33
916	160-25-F	150	9.73	.06	9.60	80.60	14849	0.36
923	240-15-F	90	5.20	1.60	11.00	82.20	14853	7.31
912	120-30-F	150	6.86	0	11.33	81.80	14853	0
917	160-27-F	180	2.60	.60	14.40	82.40	15009	2.28
924	240-20-F	60	6.40	.20	11.00	82.40	14853	1.03
927	280-15-F	60	5.60	2.00	10.60	81.80	14853	9.13
922	200-25-F	72	6.60	1.20	10.20	82.00	14853	6.06
918	160-30-F	60	4.70	.60	12.70	82.00	15009	2.57

in any of the tests and the losses in heat from the presence of CO, as shown in the last column of the table, are correspondingly small.

PERFORMANCE OF ENGINES

GENERAL ENGINE CONDITIONS—TABLE 909.

The tests in this and the following tables are arranged according to speed and cut-off, beginning with a speed of 80 revolutions per minute and a nominal cut-off of 15 per cent. The cut-off at 80 revolutions per minute was increased until it became

evident that a further increase in cut-off would result in slipping the driving wheels, should the adhesion become momentarily reduced from any cause. The limit of the boiler to supply steam was not nearly reached at this speed, nor was it quite reached at 120 revolutions, though the evaporation at 120 revolutions per minute would indicate that it is close to the limit of boiler power. At 160 revolutions per minute, or 38.2 miles per hour, the boiler power limit was reached and exceeded, and for this and the higher speeds the danger of slipping was not a factor in limiting the cut-off used.

TABLE No. 909—GENERAL ENGINE CONDITIONS.

Identification of Test		Duration of Test, Minutes	Revolutions Per Minute	Speed, Miles Per Hour	Cut-off, Per Cent. of Stroke	Steam Pressure	
Test Number	Laboratory Designation					In Boiler, Lbs., Per Sq. Inch	In Branch Pipe, Lbs., Per Sq. Inch
		(Cal)	(198)	(199)	(268) to (271)	(217)	(220)
901	80-15-F	180	80.00	19.10	15.7	201.3	198.3
902	80-20-F	180	80.00	19.10	17.9	200.1	197.3
904	80-25-F	180	79.99	19.09	23.7	198.5	192.8
906	80-30-F	180	80.00	19.01	29.7	202.6	199.8
908	120-20-F	180	120.00	28.65	18.8	201.0	197.7
910	120-25-F	180	120.00	28.65	24.9	200.5	197.5
912	120-30-F	150	120.00	28.65	31.7	202.7	197.8
913	160-15-F	180	160.00	38.20	16.7	198.0	195.0
914	160-20-F	180	160.00	38.20	20.2	202.9	198.2
916	160-25-F	150	160.00	38.20	24.9	200.0	195.0
917	160-27-F	180	160.00	38.20	27.7	188.4	185.6
918	160-30-F	60	160.00	38.20	31.5	186.1	181.8
920	200-20-F	150	200.00	47.75	19.5	202.0	197.4
922	200-25-F	72	200.00	47.75	25.5	202.1	197.1
923	240-15-F	90	240.00	57.30	19.0	196.4	194.2
924	240-20-F	60	240.00	57.30	21.6	197.5	195.1
927	280-15-F	60	280.00	66.85	19.9	194.4	191.7
929	320-15-F	—	320.17	76.08	21.4	196.3	——

Test 929, at 320 revolutions per minute, was not made as one of the regular series in which all observations were recorded, but the locomotive was run for about 20 minutes at this speed and six indicator diagrams taken. The fore and aft vibration.

due to the unbalanced reciprocating weights, is so great at this speed that it was thought best not to subject the dynamometer to these violent shocks for a longer time. It is evident also from the draw-bar pull record obtained at this speed that the dynamometer, unless protected from the effect of these forces, cannot give a true indication of the draw-bar pull.

Between the dynamometer and the locomotive are placed oil dash-pots to absorb the vibrations which are present at all speeds, and for the lower speeds the dash-pots effectually control these unbalanced forces. If it were possible to run this locomotive at 320 revolutions with a cut-off of 25 or 30 per cent., it is probable that the action of the steam in the cylinders would assist the dash-pots in reducing these forces.

It has been found that if the throttle is suddenly closed at speeds of 280 or 320 revolutions, the vibrations set up are very violent in the absence of compression in the cylinders. The locomotive could not maintain the steam pressure, however, with the cut-off greater than about 15 per cent.

From an inspection of the diagram (Fig. 910) and table 909, (items 268-272), it is apparent that tests at different speeds, while run with the reverse lever in the same notch, do not have the same actual cut-off in the cylinders, but the cut-off point becomes later as the speed increases. due, probably, to a springing of the valve motion. This effect is so marked that the locomotive will run forward at the higher speeds with the reverse lever in one of the notches of the backward motion. As shown in table 909, the cut-off increases from 15.7 per cent. at 80 revolutions per minute to 21.4 per cent. at 320 revolutions per minute, while nominal cut-off or reverse lever notch remains the same.

Mean Effective Pressure, Indicated Horse-Power and Steam Consumption—Table 910.

The steam consumption decreases as the indicated horse-power increases, and while the best result is 23.81 pounds of dry steam per indicated horse-power hour, the minimum rate of which the engines are capable does not appear to have been reached before the limit of the boiler to supply steam had been found.

TABLE No. 910—MEAN EFFECTIVE PRESSURE, INDICATED HORSE-POWER AND STEAM CONSUMPTION.

Identification of Test		Duration of Test, Minutes	Mean Effective Pressure, Lbs. Per Sq. Inch	Indicated Horse-Power	Dry Steam Per Indicated Horse-Power Hour, Lbs.
Test Number	Laboratory Designation				
		(Cal)	(Cal)	(379)	(381)
901	80-15-F	180	60.56	419.8	33.54
902	80-20-F	180	68.81	477.2	32.27
904	80-25-F	180	84.47	585.6	30.65
906	80-30-F	180	104.91	727.9	29.94
908	120-20-F	180	66.13	687.6	28.81
910	120-25-F	180	81.83	851.1	26.70
912	120-30-F	150	97.63	1015.4	26.63
913	160-15-F	180	54.02	748.8	26.75
914	160-20-F	180	59.63	826.8	25.34
916	160-25-F	150	72.96	1011.6	25.23
917	160-27-F	180	76.04	1055.0	26.50
918	160-30-F	60	81.74	1133.4	26.46
920	200-20-F	150	58.78	1018.6	24.83
922	200-25-F	72	70.59	1223.7	23.84
923	240-15-F	90	52.18	1085.4	24.60
924	240-20-F	60	55.98	1164.5	24.37
927	280-15-F	60	48.56	1178.4	23.81
929	320-15-F	—	——	1281.3	——

It is to be noted that the highest sustained output of the boiler was 30,300 pounds of steam per hour and that this gives a maximum of 1,223.7 indicated horse-power. Unless a greater supply of steam than 30,300 pounds can be obtained from the boiler, the maximum horse-power will be about 1,200 without regard to the speed. Larger horse-powers in road service or on the testing plant may be obtained for short intervals as already noted.

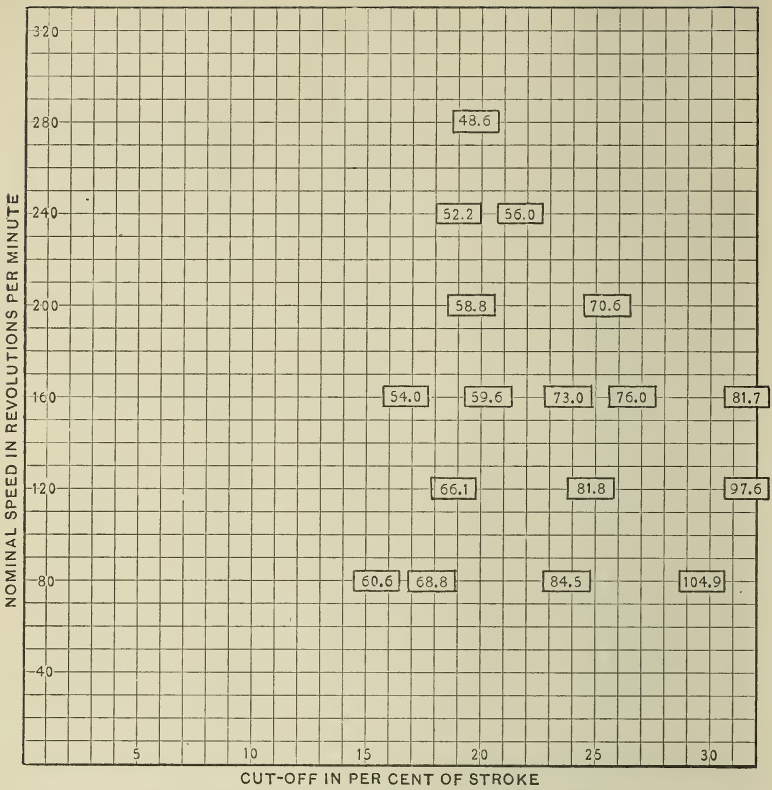


FIG. 906—MEAN EFFECTIVE PRESSURE.

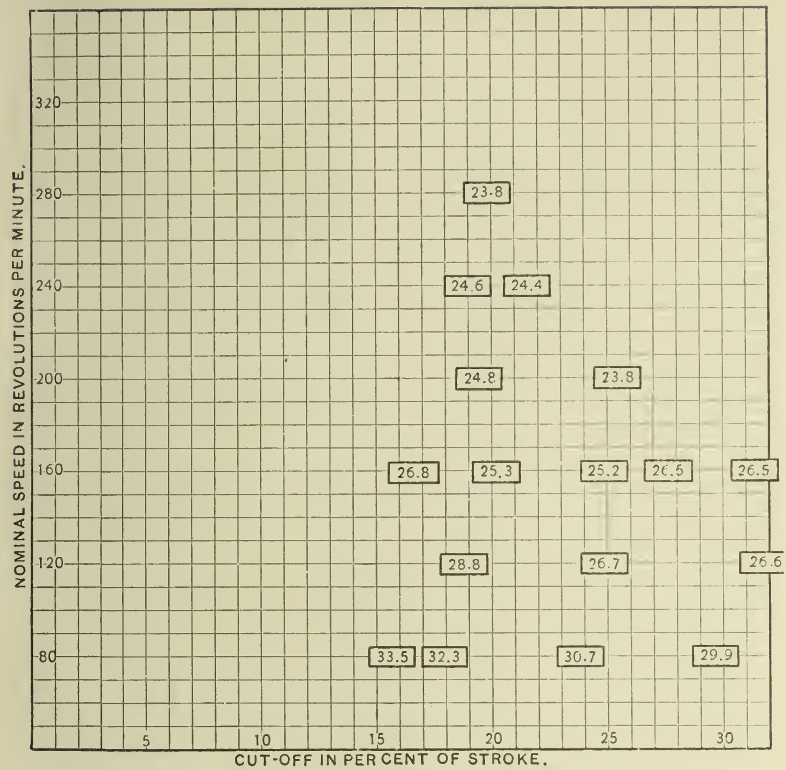


FIG. 907—DRY STEAM PER I. H. P. HOUR.

PERFORMANCE OF LOCOMOTIVES

DYNAMOMETER RECORDS—TABLE 911.

The draw-bar pull was measured by means of a lever dynamometer the details of which have been given in previous bulletins.

In the case of test 929, as explained in another place, the dynamometer reading was not correct, and the draw-bar pull and dynamometer horse-power for this test were derived from the indicated horse-power by assuming a machine efficiency of 70 per cent. for this speed.

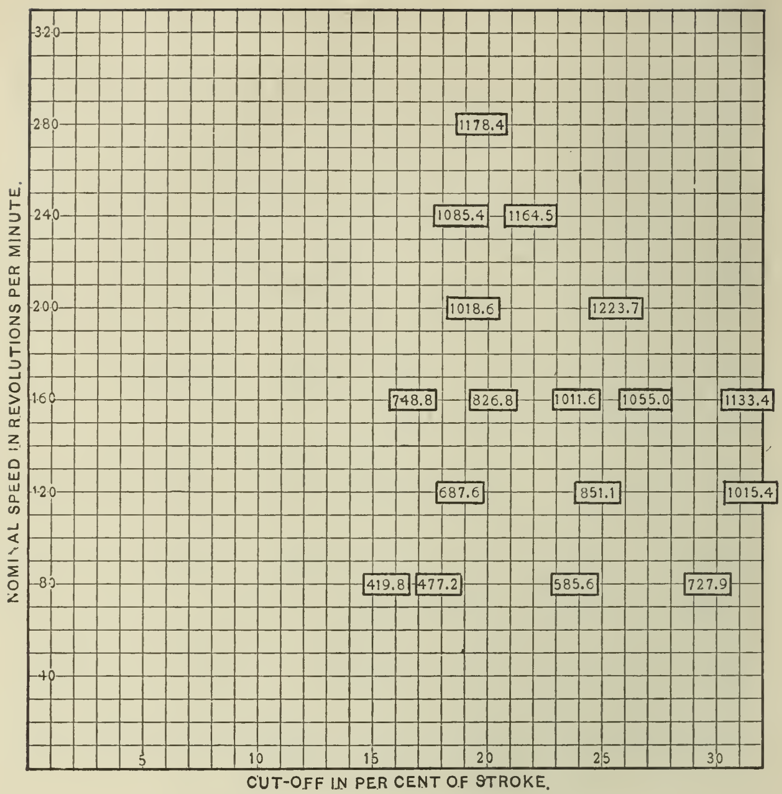


FIG. 908—TOTAL INDICATED HORSE POWER.

TABLE No. 911—DYNAMOMETER RECORDS.

Identification of Test: Test Number	Identification of Test: Laboratory Designation	Duration of Test, Minutes	Draw-bar Pull in Pounds	Dynamometer Horse-Power	Dry Coal Per D. H. P. Hour	Dry Steam Per D. H. P. Hour
		(Cal)	(265)	(383)	(384)	(385)
901	80-15-F	180	6427	327.3	5.09	43.02
902	80-20-F	180	7653	389.8	4.96	39.50
904	80-25-F	180	9810	499.6	4.36	35.92
906	80-30-F	180	12475	632.3	4.64	34.46
908	120-20-F	180	7280	556.2	4.42	35.16
910	120-25-F	180	9438	721.1	4.62	31.51
912	120-30-F	150	11785	900.8	4.43	29.59
913	160-15-F	180	5578	568.2	4.80	35.26
914	160-20-F	180	6538	665.9	4.50	31.46
916	160-25-F	150	8155	830.7	5.08	30.73
917	160-27-F	180	8757	892.1	5.38	31.34
918	160-30-F	60	9571	975.0	5.72	30.83
920	200-20-F	150	6199	789.4	4.68	32.04
922	200-25-F	72	7701	980.6	5.08	29.75
923	240-15-F	90	4940	880.7	5.77	30.31
924	240-20-F	60	5908	902.8	6.76	31.43
927	280-15-F	60	4752	847.2	5.92	33.12
929	320-15-F	—	*4424	*896.9	——	——

* Estimated.

The dry coal per dynamometer horse-power ranges from 4.42 pounds to 6.76.

Machine Friction—Table 912.

Throughout this series of tests the driving axle bearings were lubricated with oil. The main and side rods, except the front end of the main rods, were lubricated with hard grease. The cylinders were lubricated with oil by means of a sight feed lubricator.

The machine friction in draw-bar pull is a fairly uniform quantity, ranging from 1,417 to 1,909 pounds; in test 923 it is 1,148.

Maximum Power of the Locomotive.

From the diagrams (Figs. 909 and 910) the draw-bar pull that this locomotive is capable of exerting for a considerable

TABLE No. 912—MACHINE EFFICIENCY.

Identification of Test: Test Number	Identification of Test: Laboratory Designation	Duration of Test, Minutes	Machine Friction in: Horse-Power	Machine Friction in: Mean Effective Pressure, Lbs. Per Sq. Inch	Machine Friction in: Draw-Bar Pull, Pounds	Machine Efficiency, Per Cent.
		(Cal)	(395)	(396)	(397)	(398)
901	80-15-F	180	92.5	13.34	1816	77.96
902	80-20-F	180	87.4	12.57	1716	81.68
904	80-25-F	180	86.0	12.40	1689	85.35
906	80-30-F	180	95.6	13.78	1886	86.87
	Average		**90.4**	**13.02**	**1777**	
908	120-20-F	180	131.4	12.63	1652	80.89
910	120-25-F	180	130.1	12.50	1702	84.71
912	120-30-F	150	114.6	11.01	1499	88.71
	Average		**125.4**	**12.05**	**1618**	
913	160-15-F	180	180.6	13.01	1417	75.88
914	160-20-F	180	160.9	11.60	1579	80.54
916	160-25-F	150	180.9	13.03	1775	82.11
917	160-27-F	180	162.9	11.74	1599	84.56
918	160-30-F	60	158.4	11.41	1554	86.02
	Average		**168.7**	**12.16**	**1585**	
920	200-20-F	150	229.2	13.21	1805	77.49
922	200-25-F	72	243.1	14.01	1909	80.13
	Average		**236.2**	**13.61**	**1857**	
923	240-15-F	90	204.7	8.43	1148	81.14
924	240-20-F	60	261.7	12.57	1713	77.53
	Average		**233.2**	**10.50**	**1431**	
927	280-15-F	60	331.2	13.64	1858	71.89

length of time has been estimated by the method formerly used in connection with the St. Louis tests, and which will be repeated here as applied to this locomotive.

The maximum power of a locomotive depends upon the relation between the amount of water which can be evaporated by the boiler and the efficiency of the cylinders; for example, if the maximum evaporative power of a locomotive boiler is W pounds of dry steam per hour and the cylinders require N pounds of dry steam per horse-power hour, then the maximum horse-power of the locomotive is represented by $\frac{W}{N}$, except that the maximum power may be limited by the adhesion of the driving wheels at

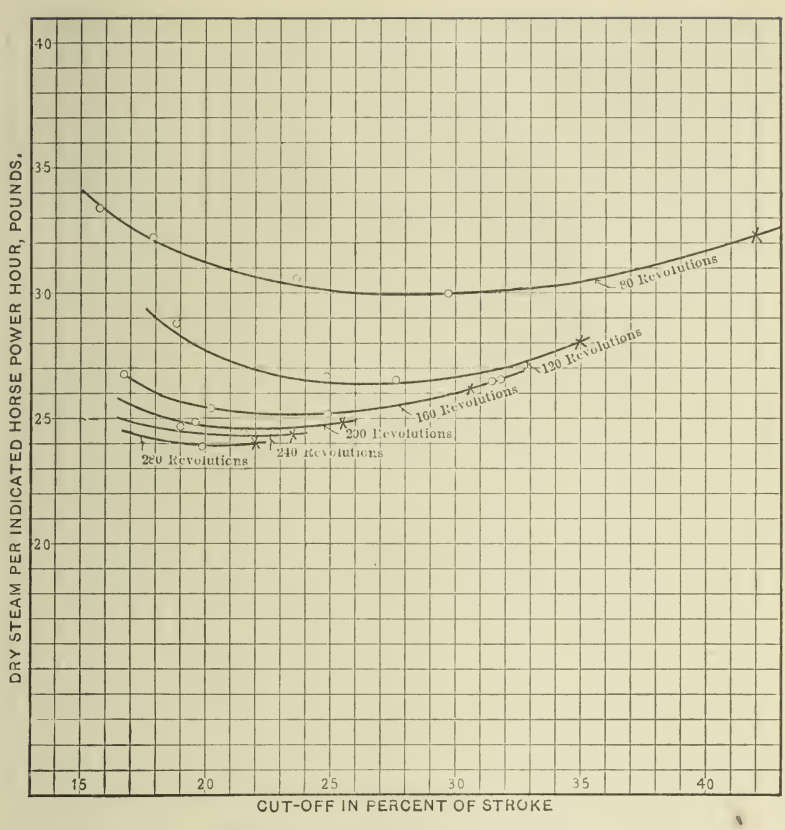


FIG. 909—STEAM CONSUMPTION.

low speeds. The maximum evaporative power of this boiler under the conditions of these tests is about 30,000 pounds of dry steam per hour. Fig. 909 shows the relation between steam consumption per indicated horse-power and cut-off at the several speeds. Similarly, Fig. 910 shows the relation between indicated horse-power and cut-off for the several speeds.

In each diagram the curves have been extended beyond the actual experimental points.

It is now only necessary to select for each speed the cut-off at which the product of indicated horse-power, as shown by Fig. 910 and steam consumption, as shown by Fig. 909, is approximately 30,000 pounds (the maximum capacity of the boiler.) These critical cut-offs are indicated on the diagrams (Figs. 909

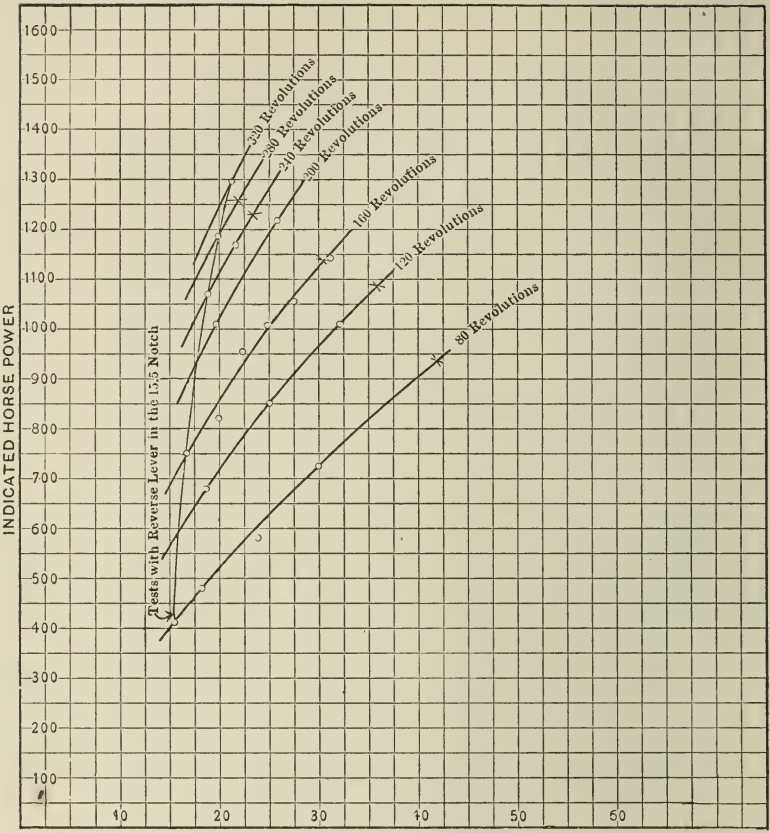


FIG. 910—INDICATED HORSE POWER.

and 910) by a cross mark, and the value of the several factors are shown in the following table:

Nominal Speed R. P. M.	Cut-off in Per Cent.	Steam Per I. H. P. Hour.	Maximum Cylinder Horse-Power.
80	42	32.3	940
120	35	28.0	1075
160	30.5	26.3	1150
200	25.5	24.9	1220
240	23.5	24.4	1240
280	22	24.0	1250

The cylinder horse-power given in the last column of the above table is what would be expected by indicator if tests had been run under the conditions of maximum power at the several

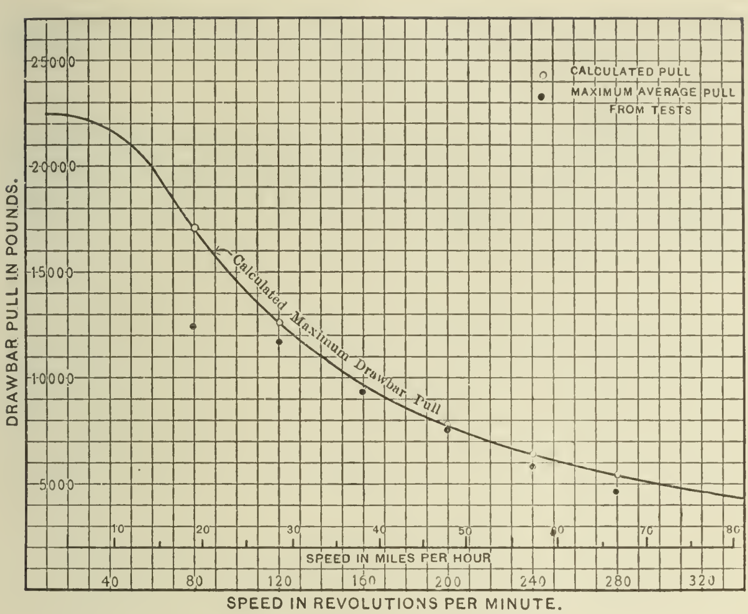


FIG. 911—MAXIMUM DRAW-BAR PULL.

speeds and cut-offs. The cylinder horse-power as found above is now reduced to an equivalent draw-bar pull by the following equation in which S is the speed in miles per hour and F is the corresponding average frictional draw-bar pull (which has been assumed as the average obtained for the whole series of tests, or 1,687 pounds):

$$\text{Maximum Draw-bar Pull} = \frac{\text{Max. Horse-power x 375}}{S} - F$$

The maximum draw-bar pulls at the several speeds, as determined from the above equation, are as follows:

Speed in R. P. M.	Max. Estimated Draw-bar Pull. Pounds.
80	16,768
120	12,384
160	9,602
200	7,894
240	6,428
280	5,325

In Fig. 911 the draw-bar pull is shown graphically with the

maximum results obtained in the tests. At speeds of 120, 160, 200, 240 and 280 the maximum pulls developed in the tests approached closely the calculated maximum.

The calculated tractive power at starting is 22,500 pounds, and it is probable that the slowest speed at which the full power of the boiler could be utilized is about 40 revolutions per minute, or about 10 miles per hour.

COMPARISON OF TWO ATLANTIC TYPE PASSENGER LOCOMOTIVES.

Of the passenger locomotives tested at St. Louis in 1904, the New York Central locomotive, No. 3000, resembled Pennsylvania Railroad locomotive No. 5266 in general dimensions, weight and class of service for which it was designed. It was, however, a four-cylinder balanced compound, while the 5266 is a simple locomotive.

In order to show a comparison of the results obtained on a simple and a compound locomotive, the following diagrams have been prepared from the results of tests on these two locomotives. Before taking up the discussion of these diagrams, however, some of the principal dimensions of the locomotives are given in parallel columns in order to show in what particulars they differ.

	N. Y. C. R. R. No. 3000.	P. R. R. No. 5266
Total weight of locomotive working order, lbs.....	200,000	184,167
Weight on drivers, locomotive, working order, lbs.	110,000	110,001
Cylinders, diameter and stroke, inches	15½x26x26	20½x26
Driving wheels, diameter, inches	79	80
Boiler, diameter, inches...	72¼	67
Tubes, number	390	315
" diameter, inches...	2	2
" length, " ...	191.29	179.78
Heating surface, fire-box, (fire side), sq. ft.......	202.83	156.86
Heating surface, tubes (fire side), sq. ft.......	2848.36	2162.4
Heating surface, total (fire side), sq. ft.......	3051.19	2319.26
Grate area, sq. ft........	49.9	55.5
Ratio heating surface to grate surface	61.10	41.79
Boiler volume, cubic feet steam space	77.41	109.9
Boiler volume, cubic feet water space	331.66	338.6

Boiler Performance.

The coal used was that from the Scalp Level mines of the Berwind-White Coal Mining Company, both for the 3000 at St. Louis and the 5266 at Altoona.

In Fig. 1, where the fire-box and smoke-box temperatures are plotted, the differences between the two locomotives are small. The 3000 had a brick arch in the fire-box, but no difference in

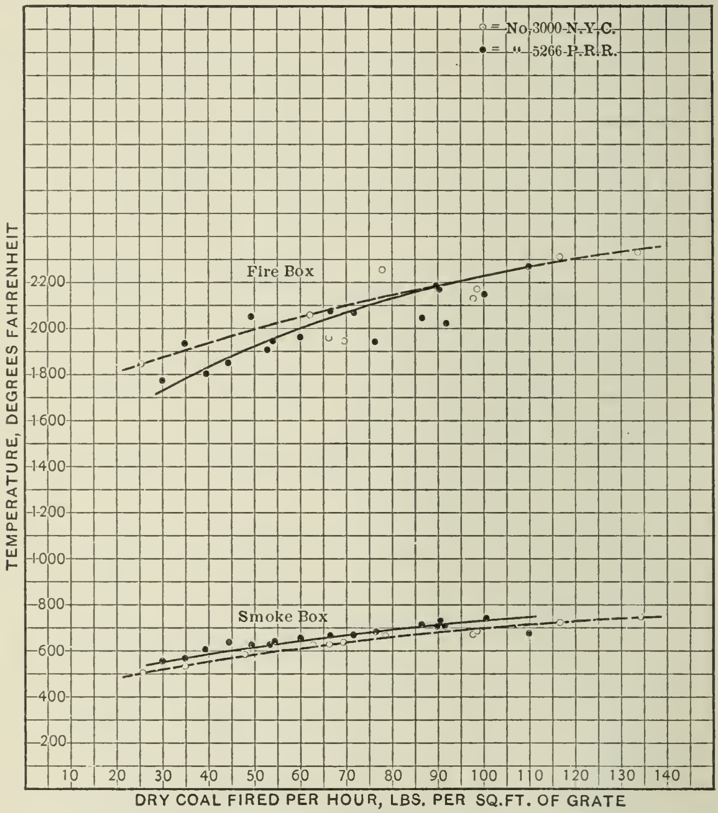


FIG. 1—FIRE BOX AND SMOKE BOX TEMPERATURES.

fire-box temperature is evident as due to this cause. The smoke-box temperature of the 3000, which had a greater length of tube than the 5266, is shown to be lower throughout the tests, indicating that this greater tube length absorbed a larger part of the heat in the gases of combustion than the shorter tubes of he 5266.

In Fig. 2, where the equivalent evaporation per pound of dry coal is given for different rates of evaporation per square

foot of heating surface, no difference is found between the two boilers. In other words, the efficiency of a square foot of heating surface in the boiler of 5266 is the same as the efficiency of a square foot of heating surface in the boiler of No. 3000, and this is true for all rates of evaporation.

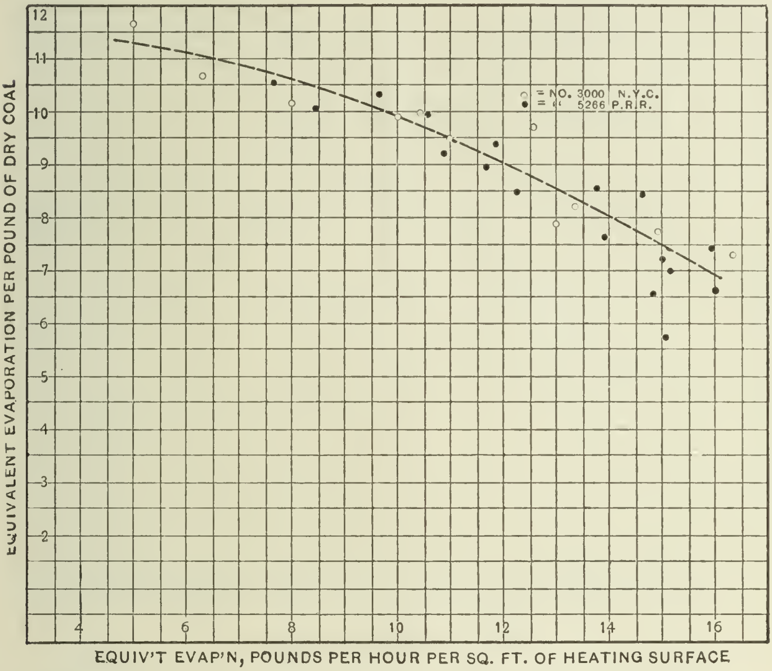


FIG. 2—EVAPORATION.

For two boilers so similar in general type this is to be expected, as there is no reason to suppose that the heating surfaces of the two boilers will have materially different rates of heat transmission to the water when the steel plates are clean as in the case of these two boilers. When, however, the equivalent evaporation per pound of coal is plotted according to the rate of combustion as in Fig. 3, the advantage of the larger heating surface per foot of grate in the 3000 is at once apparent, and this advantage of the 3000 in economical evaporation is maintained throughout the full range of steam delivery of the two boilers.

The highest equivalent evaporation per square foot of heating surface is nearly the same for each boiler, being 16.34 pounds per hour in the case of the 3000 and 16.03 pounds for the 5266.

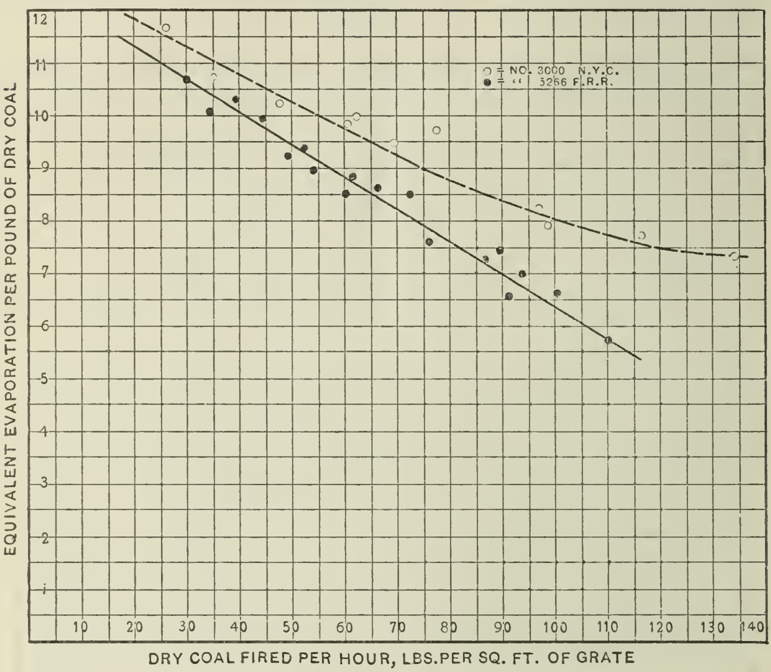


FIG. 3—EVAPORATION.

With the boiler of No. 3000 the greatest loss of heat due to the presence of carbon monoxide in the products of combustion, or, in other words, the greatest loss due to poor combustion was but 1¼ per cent., and in only one other test was it as much as 1 per cent. In the case of the 5266, the losses, while in all cases comparatively small, are in one tesst 9.13 per cent., and in two others 6.06 per cent. and 7.3 per cent. The very perfect combustion shown by the 3000 is, in all probability, due to the brick arch in the fire-box of this locomotive. There was no arch in the 5266.

The 3000 was fitted with smoke-box deflectors or diaphragms which made the smoke-box completely self-cleaning, while the 5266 did not have a self-cleaning front, and this was one of the

limiting factors in maximum evaporation obtained with long cut-offs, due to the accumulation of cinders in the front end, which

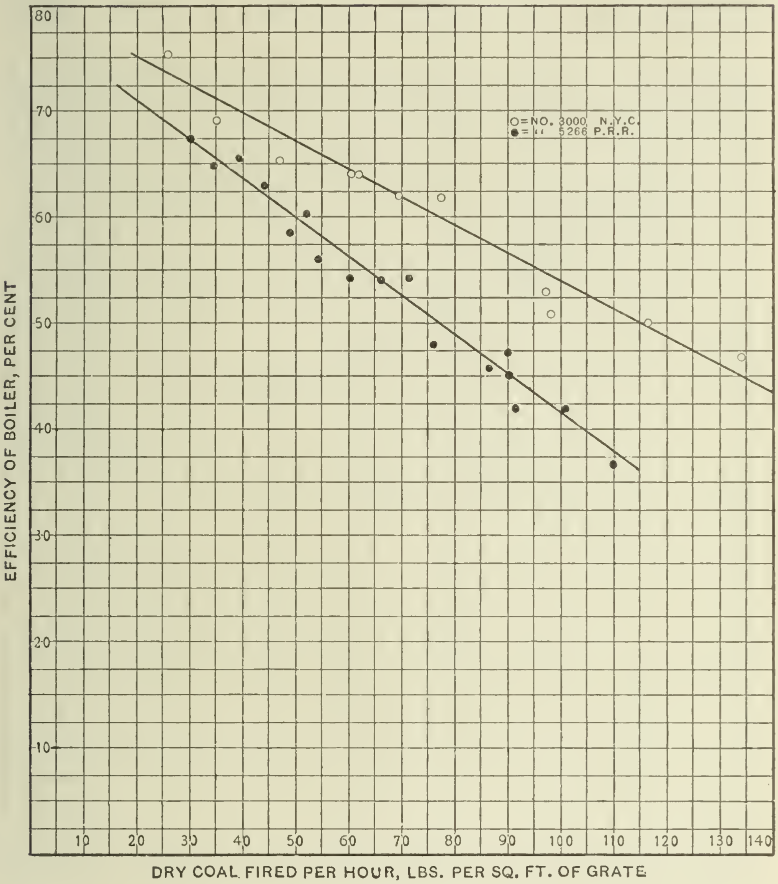


FIG. 4—BOILER EFFICIENCY.

interfered with the draft, and, consequently, the steaming capacity. The results from the action of the two smoke-boxes are shown in Figure 5½.

Engine Performance.

In Fig. 5 the well-established fact that the engines of a compound locomotive within limits, operate on less steam per unit of power than the engines of a simple locomotive, is shown.

The diagram shows very clearly another fact that is not so

generally recognized, and that is that the difference in the water rate or steam per horse-power hour is not a constant difference expressable as a certain definite percentage of saving. When

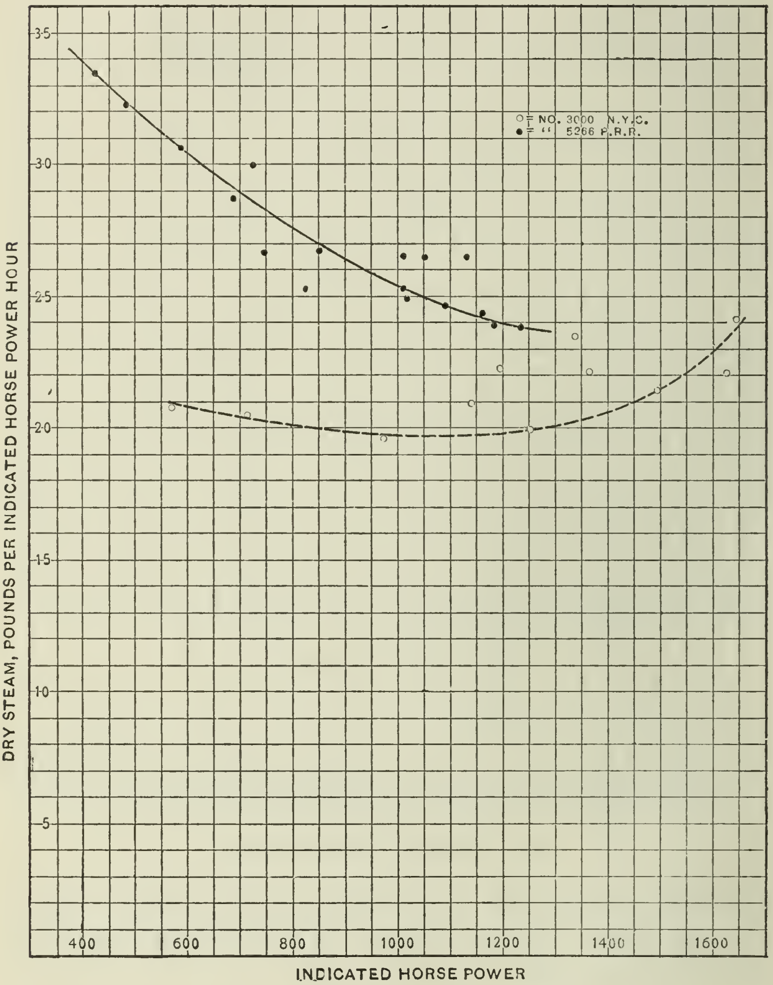


FIG. 5—STEAM PER INDICATED HORSE POWER.

each of the locomotives is developing 600 horse-power, there is a difference in the steam per horse-power of about 9.7 pounds, or a saving of 31.8 per cent., while at 1300 horse-power the saving is but 3.5 pounds, or 14.9 per cent.

FIG. 5½—CINDERS IN SMOKE BOX.

The two curves show that the water rates of the two locomotives would, perhaps, meet at about 1600 horse-power were it possible to drive the 5266 to such a point, and as the high horse-

powers were obtained, as a rule, at the higher speeds, the curves would indicate that the simple locomotive is working most economically at its highest speeds, while the reverse is true of the compound.

It will be remembered that in the case of the simple and compound freight locomotives tested at St. Louis the conclusions arrived at in regard to the steam consumption were as follows: "In general the steam consumption of the simple engines decreased with increase in speed, while that of the compounds increased, which would lead to the conclusion that the steam distribution of the compounds was less satisfactory at high speeds than that of the simple."* The maximum horse-power developed by the 3000 was 1641, while the maximum for the 5266 was 1281.

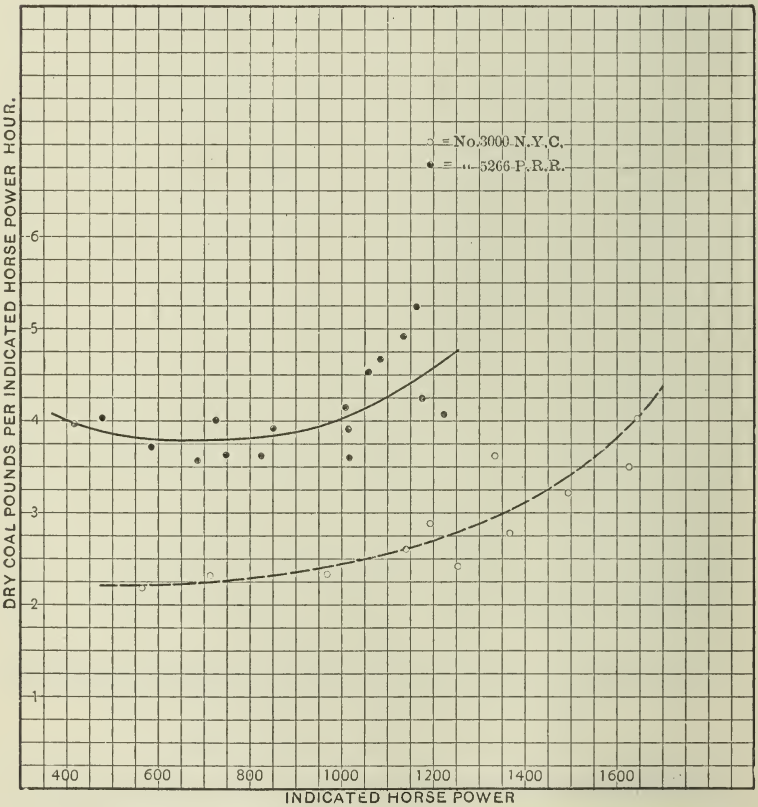


FIG. 6—COAL PER INDICATED HORSE POWER.

* See "Locomotive Tests and Exhibits," page 706.

In Fig. 2 we have seen that the evaporation per pound of coal decreases as the output of the boiler in steam increases, and this decrease explains the difference in the appearance of the curves in Figs. 5 and 6. It would appear at first sight as though the curves for coal per indicated horse-power hour should follow the same law as do the curves for steam, and this would be the case if it were not for the fact that as the output of the boiler increases, it is at the expense of a greater and greater quantity of coal per pound of water evaporated.

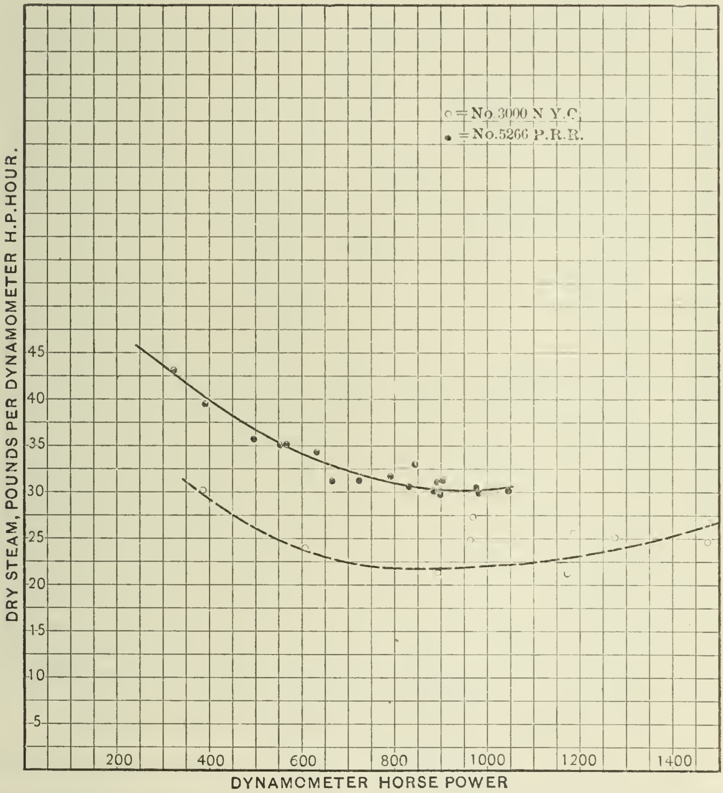


FIG. 7—STEAM PER DYNAMOMETER HORSE POWER.

Locomotive Performance.

In Fig. 10 is shown the dry steam used by the locomotives at different indicated horse-powers. The 3000, compound, requires at all powers less steam than the 5266, simple locomotive,

but as the limit of power is approached by the compound the steam rate advances more rapidly than would apparently be the case with a simple locomotive. This is only another way of showing that the advantage of compounding may not be realized at high speeds, as was developed in the discussion of Fig. 5, as judged by the two locomotives under discussion.

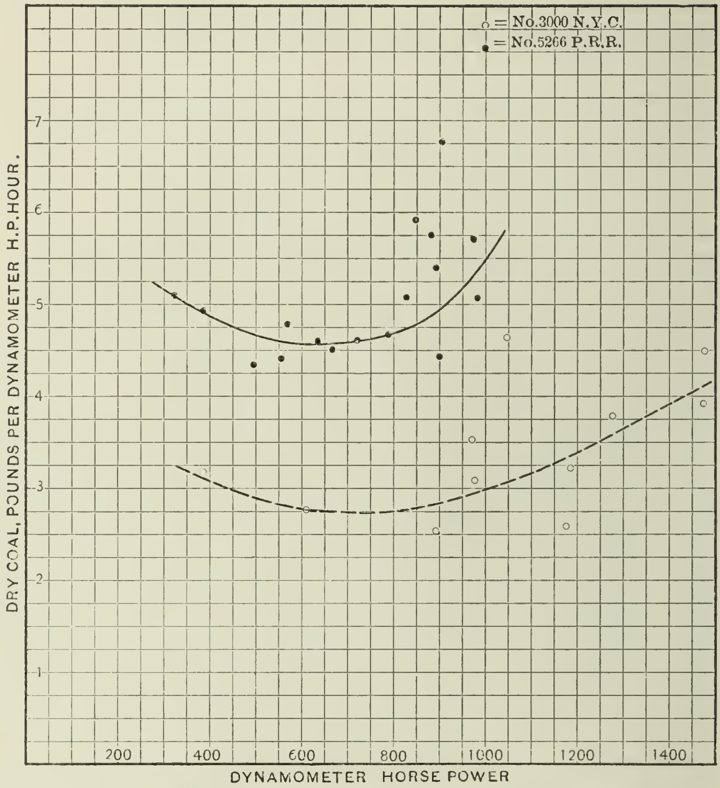


FIG. 8—COAL PER DYNAMOMETER HORSE POWER.

One of the most significant results of this comparison of a simple with a compound locomotive is the large increase in horse-power and draw-bar pull that can be realized from compounding without any increase in the boiler capacity. This is a very important advantage aside from all considerations of economy in the use of fuel.

Let us assume that the boiler of each locomotive will deliver 30,000 pounds of dry steam per hour to the engines. With this weight of steam the simple locomotive, No. 5266, will develop

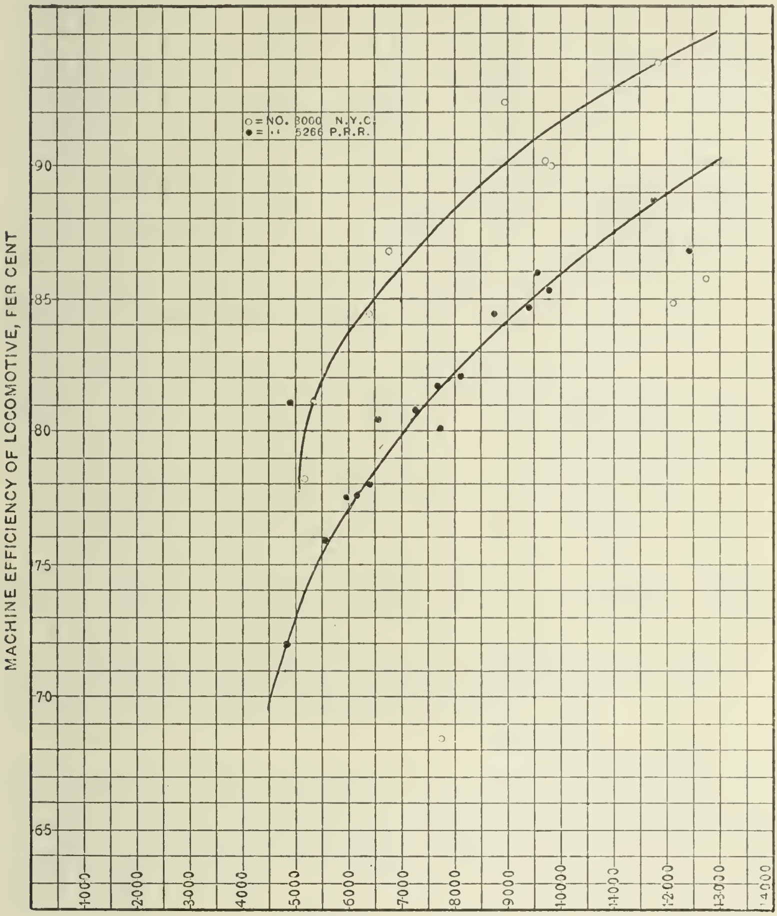


FIG. 9—MACHINE EFFICIENCY.

1200 indicated horse-power, while the compound, No. 3000, will develop 1400 indicated horse-power. To show what this will mean in increased draw-bar pull, due to compounding at several speeds, the following table has been arranged:

Comparative Performance.

At 40 miles per hour, using 30,000 pounds of water per hour:

Locomotive	Type	Machine Efficiency	Indicated Horse Power	Dynamometer Horse Power	Draw-Bar Pull	Increase in Draw-Bar Pull from Compounding
5266	4—4—2 Simple	86	1200	1032	9674	
3000	4—4—2 Compound	86	1400	1204	11287	+1613

At 50 miles per hour, using 30,000 pounds of water per hour:

5266	Simple	79	1200	948	7110	
3000	Compound	79	1400	1106	8294	+1184

At 60 miles per hour, using 30,000 pounds of water per hour:

5266	Simple	77	1200	924	5775	
3000	Compound	77	1400	1078	6737	+ 962

The above table shows what might be expected in increased power if the cylinders of locomotive No. 3000 were to be applied to locomotive No. 5266.

The probable result in fuel saving with this combination of the compound cylinders and the boiler of No. 5266, working as before at about its maximum rate of evaporation, that is, delivering 30,000 pounds of dry steam per hour, will be as shown in the following table.

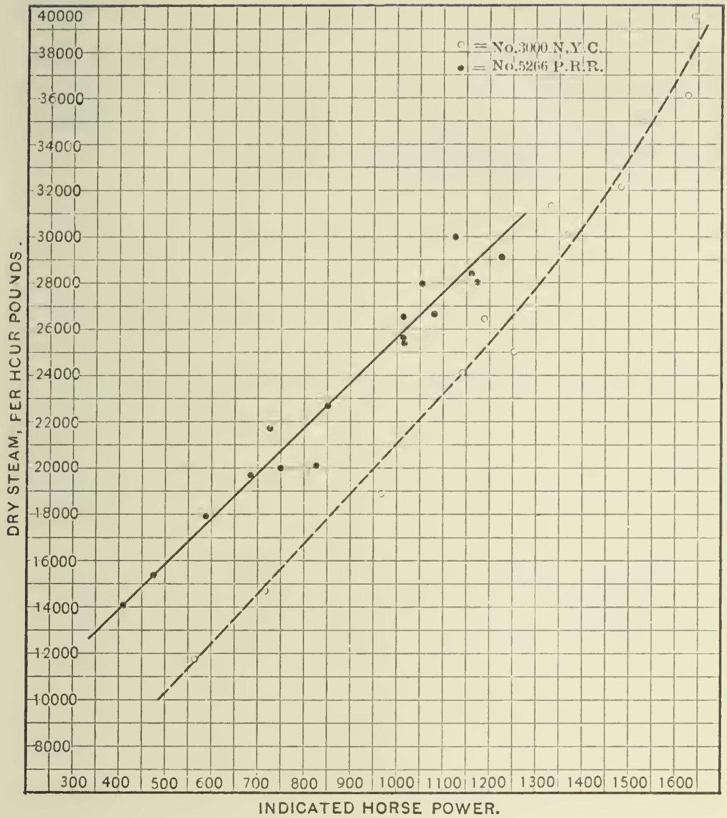


FIG. 10—STEAM AND HORSE POWER.

Coal Per Dynamometer Horse-Power Hour for Locomotive 5266, With Its Present Simple Cylinders and the Results to be Expected If the Present Boiler Were to be Fitted With Compound Cylinders Similar to Those on No. 3000:

Assumed Evaporation Lbs. of Dry Steam Per Hour	Corresponding Dry Coal Burned Per Hour, Pounds	Dynamometer Horse Power Locomotive With		Speed, Miles Per Hour	Dry Coal Per Dynamometer H. P. Hour.		Difference in Favor of Compound Cylinders, Pounds of Coal	Saving Expressed as a Percentage
		Simple Cylinders	Compound Cylinders		Locomotive With Simple Cylinders	Same Boiler With Compound Cylinders		
30,000	4983	1032	1204	40	4.82	4.13	.69	14.3
30,000	4983	948	1106	50	5.25	4.51	.74	14.1
30,000	4983	924	1078	60	5.39	4.62	.77	14.3

It will be noted that this percentage of saving agrees closely with that observed under engine performance. It is also the saving at a point where the simple locomotive is at its best, as before noted, namely, at its maximum horse-power. Other lower rates of evaporation might be selected where percentages of saving would be much higher.

APPENDIX

The appendix contains:

1. Description, dimensions and proportions of the locomotive. (pp. 48 to 53 inclusive.

2. Summary of average results of tests. (pp. 54 to 64 inclusive.

3. Graphical running logs showing boiler pressure, total water, total coal, revolutions per minute, and draw-bar pull for each test. Each diagram was plotted during the test to which it refers. (pp. 65 to 73 inclusive.)

4. Plots showing relations between important items of the tests. (pp. 74 to 103 inclusive.)

5. Vibration Diagrams. (pp. 104 to 106 inclusive.)

6. Typical indicator diagrams. A representative set of diagrams from each test is shown. (pp. 107 to 111 inclusive.)

7. A typical dynamometer diagram for each nominal speed. (pp. 112 to 115.)

8. Illustrations of the locomotive showing important details and location of testing instruments.

Description, Dimensions and Proportions of Pennsylvania E2a Atlantic (4-4-2) Type Locomotive No. 5266.

Built at the Juniata Shops of the Pennsylvania Railroad, Altoona, Pa., July, 1904.

Driving Wheels.

1	Number of pairs			2
2	Approximate diameter, inches			80
	MEASURED CIRCUMFERENCE, FEET.		After March 1, 1907.	
3	Right, No. 1	20.91		21.01
4	" " 2	20.91		21.01
5	" " 3			——
6	" " 4			——
7	" " 5			——
8	Left, " 1	20.91		21.01
9	" " 2	20.91		21.01
10	" " 3			——
11	" " 4			——
12	" " 5			——
13	Average	20.91		21.01

ENGINE TRUCK WHEELS.

14	Number	4
15	Diameter, inches	36

TRAILING WHEELS.

16	Diameter, inches	50

WHEEL BASE, FEET.

17	Driving wheel base	7.42
18	Total wheel base	30.85
19	Gauge of wheels, in inches	56.13

WEIGHT OF ENGINE WITH WATER AT SECOND GAUGE COCK AND NORMAL FIRE, IN POUNDS.

20	On truck	37,167
21	" 1st drivers	53,334
22	" 2nd "	56,667
23	" 3rd "	——
24	" 4th "	——
25	" 5th "	——
26	" trailers	37,000
27	Total	184,167
28	" on drivers	110,001

CYLINDERS.

29	High pressure, number	2
30	Low " "	——
31	Arrangement	Outside

DIAMETER, INCHES.

32	High pressure, right	20.518
33	" " left	20.812
34	Low " right	——
35	" " left	——

STROKE OF PISTON, FEET.

36	High pressure, right	2.164
37	" " left	2.164
38	Low " right	——
39	" " left	——

CLEARANCE PER CENT. OF PISTON DISPLACEMENT.

40	H. P., right, head end	12.7
41	" " crank "	12.1
42	" left, head "	12.4
43	" " crank "	11.9
44	L. P., right, head end	——
45	" " crank "	——
46	" left, head "	——
47	" " crank "	——

RECEIVER, CUBIC FEET.

48	Volume, right side	——
49	" left "	——

STEAM PORTS, INCHES.

(*For piston valves the length equals the circumference of inside of bushing minus the sum of the widths of bridges.*)

50	H. P. admission, right, head end, length	19.87
51	" " " " " width	1.48
52	" " " crank " length	19.82
53	" " " " " width	1.48
54	" " left, head " length	19.83
55	" " " " " width	1.48
56	" " " crank " length	19.86
57	" " " " " width	1.48
58	L. P. " right, head " length	——
59	" " " " " width	——
60	" " " crank " length	——
61	" " " " " width	——
62	" " left, head " length	——
63	" " " " " width	——
64	" " " crank " length	——
65	" " " " " width	——
66	H. P. exhaust, right, length	19.84
67	" " " width	2.98
68	" " left, length	19.92
69	" " " width	2.98

70	L. P. " right, length	——
71	" " " width	——
72	" " left, length	——
73	" " " width	——

PISTON RODS, DIAMETER, INCHES.

74	High pressure, right	3.472
75	" " left	3.501
76	Low " right	——
77	" " left	——

TAIL RODS, DIAMETER, INCHES.

78	High pressure, right	——
79	" " left	——
80	Low " right	——
81	" " left	——

VALVES.

82	Type	Wilson Balanced Double Ported Slide
83	Design	American Balance Valve Co.
84	Per cent. of balanced to total area	75.70
85	Type of link motion	Stephenson

GREATEST VALVE TRAVEL, INCHES.

86	High pressure, right	7.0
87	" " left	7.2
88	Low " right	——
89	" " left	——

OUTSIDE LAP OF VALVE, INCHES.

90	High pressure, right, head end	1.5
91	" " " crank "	1.5
92	" " left head "	1.5
93	" " " crank "	1.5
94	Low " right, head "	——
95	" " " crank "	——
96	" " left, head "	——
97	" " " crank "	——

INSIDE LAP OF VALVE, INCHES.

98	High pressure, right, head end ....negative	.16
99	" " " crank "	.16
100	" " left, head "	.14
101	" " " crank "	.14
102	Low " right, head "	——
103	" " " crank "	——
104	" " left, head "	——
105	" " " crank "	——

MISCELLANEOUS.

106	Cylinder lagging material	Magnesia
107	" jacket "	Sheet iron
108	Lead, forward motion, right	$\frac{11}{64}$ negative
109	" " " left	$\frac{4}{64}$ "

110	Area of steam port in valve, sq. in.	8.20
111	" " exhaust " " " " "	8.20
112		

BOILER.

113	Type	Belpaire, wide fire-box
114	Outside diameter, first ring, inches	67.0

TUBES.

115	Number	315
116	Outside diameter, inches	2.00
117	Thickness, inches	.125
118	Length between tube sheets, inches	179.78
119	Total fire area, square feet	5.26
120	Serve Tubes, number of ribs	———
121	" " sq. in. of inside surface in one in. of length	———
122		
123		
124	Boiler pressure, lbs. per sq. in	205

SUPERHEATER.

125	Number of tubes	——
126	Outside diameter, inches	——
127	Thickness, inches	——
128	Length of tubes, inches	——
129		
130		
131		

FIRE-BOX (SIZE INSIDE, INCHES).

132	Length	114.0
133	Width	68.0
134	Depth, front end	61.0
135	" back "	55.25
136	Volume, cubic feet (no arch)	233.31
137	Air inlets to ashpan (dampers closed), sq. ft.	0.0
138	" " " " (" open), " "	2.3
139	" " " " increased, 11-27-'06, to	6.3
140		

FIRE DOORS.

141	Number	1
142	Area, square feet	1.59
143		

GRATES.

144	Style	Rocking finger
145	Total area, square feet	55.5
146	" " dead grates, square feet	6.0
147	Width of air spaces, inches	.75

AIR INLET AREAS, SQUARE FEET.

148	Through fire-box sides	.00
149	" grates	15.00
150	" fire doors	.03

151	Total air inlets, (148), (149) and (150)	15.03
152	Ratio " " (149) to grate area (145)	0.27
153	" " " (151) " " " (145)	0.27

HEATING SURFACE, SQUARE FEET.

154	Of the tubes, water side	2471.04
155	" " " fire "	2162.40
156	" " fire-box, fire side	156.86
157	" " superheater, fire side	———
158	Total, based on inside of fire-box and inside of tubes	2319.26
159	Total, based on inside of fire-box and outside of tubes	2627.90

BOILER VOLUMES.

With water surface at level of second gauge cock.

160	Water space, cubic feet	338.6
161	Steam " " "	109.9

EXHAUST NOZZLE.

162	Double or single	Single
163	Size of right, inches } Diam	5.625
164	" " left, " }	
165	Area of right, square inches }	24.85
166	" " left, " " }	
167	Total area, square inches	24.85

REVERSE LEVER.

168	H. P. cylinder, notches forward of centre	15
169	L. P. " " " " "	
170		

RATIOS.

171	Heating surface (158) to grate area (145)	41.79
172	Fire area through tubes (119) to grate area (145)	.09
173	Fire-box heating surface (156) to grate area (145)	2.83
174	Tube surface (155) to fire-box heating surface (156)	13.79
175	Fire-box volume (136) to grate area (145)	4.20
176		
177		
178		

CONSTANTS FOR DYNAMOMETER HORSE POWER.

(*Power developed at one R. P. M. when pull is one pound.*)

179		.0006367 and .0006336

CONSTANTS FOR INDICATED HORSE POWER.

(*Power developed at one R. P. M. and one pound M. E. P.*)

180	High pressure, cylinder, right, head end	.02168
181	" " " " crank "	.02106
182	" " " left head "	.02231
183	" " " " crank "	.02168
184	Low " " right, head "	———
185	" " " " crank "	———
186	" " " left, head "	———
187	" " " " crank "	———

PISTON DISPLACEMENT, CUBIC FEET.

188	High	pressure	cylinder,	right	head	end	....	4.97
189	"	"	"	"	crank	"	....	4.83
190	"	"	"	left,	head	"	....	5.11
191	"	"	"	"	crank	"	....	4.97
192	Low	"	"	right,	head	"	....	——
193	"	"	"	"	crank	"	....	——
194	"	"	"	left,	head	"	....	——
195	"	"	"	"	crank	"	....	——

SUMMARY OF AVERAGE RESULTS—LOCOMOTIVE No. 5266.
PENNSYLVANIA RAILROAD COMPANY.

Test Number	Laboratory Designation	Hours Duration of Test	Speed: Revolutions: Total	Speed: Revolutions: Average Per Minute	Speed: Equivalent: Speed in Miles Per Hour	Speed: Equivalent: Piston Speed in Feet Per Minute	Position of Levers: Reverse Notches from Front End	Position of Levers	Position of Levers: Throttle	Coal Loss Due to Steam Loss, Pounds Per Hour	
		196	197	198	199	200	201	202	203	204	205
901	80-15-F	3.00	14400	80.00	19.10	346.2	15.5		Full	51.15	
902	80-20-F	3.00	14400	80.00	19.10	346.2	15.0		"	64.40	
904	80-25-F	3.00	14398	79.99	19.09	346.2	14.0		"	46.08	
906	80-30-F	3.00	14401	80.00	19.01	346.2	13.0		"	66.58	
908	120-20-F	3.00	21600	120.00	28.65	519.2	15.0		"	47.78	
910	120-25-F	3.00	21600	120.00	28.65	519.2	14.0		"	56.80	
912	120-30-F	2.50	18000	120.00	28.65	519.2	14.0		"	111.90	
913	160-15-F	3.00	28800	160.00	38.20	632.4	15.5		"	70.52	
914	160-20-F	3.00	28800	160.00	38.20	692.4	15.0		"	120.00	
916	160-25-F	2.50	24000	160.00	38.20	692.4	14.0		"	104.00	
917	160-27-F	3.00	28800	160.00	38.20	692.4	13.5		"	72.42	
918	160-30-F	1.00	9600	160.00	38.20	692.4	13.0		"	66.06	
920	200-20-F	2.50	30000	200.00	47.75	865.6	15.0		"	79.43	
922	200-25-F	1.20	14400	200.00	47.75	865.6	14.0		"	138.20	
923	240-15-F	1.50	21600	240.00	57.30	1038.8	15.5		"	71.48	
924	240-20-F	1.00	14400	240.00	57.30	1038.8	15.0		"	2.37	
927	280-15-F	1.00	16800	280.00	66.85	1211.8	15.5		"	94.91	
929	320-15-F	——	——	——	76.08	——	15.5		"	——	

Test Number	Laboratory Designation	Temperature, Degrees Fahrenheit, of: Smoke Box: By Thermometer	Smoke Box: By Pyrometer	Laboratory: Wet Bulb	Laboratory: Dry Bulb	Steam in Branch Pipe	Feed Water	Fire Box By Pyrometer				Steam Lost from Boiler, Lbs. Per Hr.
		206	207	208	209	210	211	212	213	214	215	216
901	80-15-F		502	61.0	54.0	386.8	48.0	1774				446
902	80-20-F		579	64.0	54.5	386.5	46.4	1918				530
904	80-25-F		618	65.0	58.3	388.8	48.0	1803				388
906	80-30-F		630	59.0	48.0	387.5	40.0	1915				506
908	120-20-F		644	69.3	62.8	390.8	48.5	1859				388
910	120-25-F		672	61.8	52.3	398.6	47.6	1965				388
912	120-30-F		665	64.0	57.0	399.1	42.2	2077				770
913	160-15-F		633	60.0	53.5	395.2	45.2	2078				537
914	160-20-F		654	55.5	45.5	398.6	43.7	1952				874
916	160-25-F		681	46.5	42.0	404.2	42.2	1935				645
917	160-27-F		719	60.0	53.5	417.2	46.8	2058				428
918	160-30-F		740	61.5	50.0	418.4	50.1	2143				360
920	200-20-F		679	53.0	49.0	403.6	42.6	2076				556
922	200-25-F		694	54.0	48.0	408.7	41.8	2180				832
923	240-15-F		693	60.5	52.0	400.9	40.8	2025				381
924	240-20-F		675	61.0	51.0	401.8	40.5	2266				11
927	280-15-F		715	51.5	45.0	398.8	41.0	2165				541
929	320-15-F		——	——	——	——	——	——				——

SUMMARY OF AVERAGE RESULTS—LOCOMOTIVE No. 5266.
PENNSYLVANIA RAILROAD COMPANY.

Test Number	Laboratory Designation	Pressure, Lbs. Per Sq. In.					Draft, Inches of Water				Injectors	
		In Boiler					In Smoke Box				Hrs. in Action	
		Average	Maximum	Minimum	In Branch Pipe	Air in Laboratory Barometric	Front of Diaphragm	Back of Diaphragm	In Fire Box	In Ash Pan	Total, Right	Total, Left
		217	218	219	220	221	222	223	224	225	226	227
901	80-15-F	201.3	205.0	196.0	198.3	14.06	2.0	1.8	0.6	0.2	2.9	0
902	80-20-F	200.1	206.0	196.0	197.3	14.16	2.1	1.9	0.8	0.1	2.9	0
904	80-25-F	198.5	201.5	196.0	192.8	14.19	3.3	3.1	1.4	0.7	3.0	0
906	80-30-F	202.6	211.0	195.0	199.8	14.15	3.4	2.9	0.7	0.3	3.0	0
908	120-20-F	201.0	203.0	197.0	197.7	14.06	3.9	3.4	1.7	0.7	3.0	0
910	120-25-F	200.5	203.5	197.0	197.5	14.12	5.1	4.5	2.3	1.0	3.0	0
912	120-30-F	202.7	206.5	191.0	197.8	14.10	4.9	4.2	1.4	0.3	2.49	0
913	160-15-F	198.0	204.0	173.0	195.0	14.24	3.1	2.8	0.9	0.2	2.81	0
914	160-20-F	202.9	206.0	200.0	198.2	14.30	3.7	3.2	1.2	0.2	3.00	0
916	160-25-F	200.0	205.0	197.0	195.0	14.37	5.2	4.4	1.5	0.3	2.50	0
917	160-27-F	188.4	204.5	171.0	185.6	14.15	7.7	6.2	2.1	0.3	3.0	0
918	160-30-F	186.1	195.5	176.0	181.8	14.11	8.9	8.0	3.0	1.3	1.0	0
920	200-20-F	202.0	205.0	199.0	197.4	14.12	5.0	4.2	1.3	0.2	2.5	0
922	200-25-F	202.1	205.5	197.0	197.1	14.30	6.0	5.1	1.6	0.3	1.2	0
923	240-15-F	196.4	205.0	181.0	194.2	13.97	5.6	4.7	1.3	0.2	1.5	0
924	240-20-F	197.5	203.0	191.0	195.1	14.04	5.4	4.6	1.4	0.3	1.0	0
927	280-15-F	194.4	207.0	182.0	191.7	14.03	5.6	4.9	1.5	0.2	1.0	0
929	320-15-F	—	—	—	—	—	—	—	—	—	—	—

Test Number	Laboratory Designation	Quality of Steam				Coal, Sparks and Ash, Pounds					
						Coal Fired			Total		
		In Dome	In Branch Pipe	Degrees of Superheat in Branch Pipe	Factor of Correction Dome	Kind	Total	Per Cent. of Moisture	Dry Coal Fired	Combustible By Analysis	Ash by Analysis
		228	229	230	231	232	233	234	235	236	237
901	80-15-F	.9856	.9983	0	.9898	Bituminous	5134	2.72	4994	4723	271
902	80-20-F	.9866	.9997	—	.9905	"	5872	1.20	5802	5392	409
904	80-25-F	.9860	1.0022	4.00	.9901	"	6598	1.04	6530	6140	397
906	80-30-F	.9845	.9994	0	.9891	"	8896	1.11	8797	8212	585
908	120-20-F	.9860	1.0024	4.2	.9901	"	7442	1.04	7365	6926	448
910	120-25-F	.9860	1.0069	12.08	.9901	"	10112	1.04	10000	9410	608
912	120-30-F	.9851	1.0071	12.43	.9895	"	10107	1.35	9970	9335	634
913	160-15-F	.9864	1.0055	9.6	.9904	"	8415	2.72	8186	7742	444
914	160-20-F	.9854	1.0067	11.72	.9897	"	9247	2.72	8995	8508	487
916	120-25-F	.9859	1.0106	18.57	.9901	"	10848	2.72	10552	9981	572
917	160-27-F	.9860	1.0202	35.51	.9901	"	14557	1.04	14405	13547	876
918	160-30-F	.9860	1.0218	38.38	.9901	"	5640	1.04	5581	5249	339
920	200-20-F	.9856	1.0098	17.16	.9899	"	9494	2.72	9235	8735	500
922	200-25-F	.9859	1.0127	22.23	.9901	"	6062	1.35	5980	5599	381
923	240-14-F	.9850	1.0091	15.93	.9894	"	7706	1.11	7620	7113	507
924	240-20-F	.9860	1.0093	16.29	.9901	"	6169	1.11	6101	5695	406
927	280-15-F	.9854	1.0084	14.73	.9897	"	5068	1.11	5012	4678	333
929	320-15-F	—	—	—	—	"	—	—	—	—	—

SUMMARY OF AVERAGE RESULTS—LOCOMOTIVE No. 5266, PENNSYLVANIA RAILROAD COMPANY.

Test Number	Laboratory Designation	Coal, Sparks and Ash, Lbs. Per Hour			Analysis of Coal Per Cent.						
		Cinders Collected in Smoke Box	Sparks Discharged From Stack	Cinders and Sparks	Fixed Carbon	Volatile Matter	Moisture	Ash	Sulphur; Determined Separately		
		238	239	240	241	242	243	244	245	246	247
901	80-15-F	52	16	68	75.87	16.14	2.72	5.27	0.91		
902	80-20-F	46	10	56	76.06	15.77	1.20	6.97	1.57		
904	80-25-F	82	16	98	76.98	15.96	1.04	6.02	0.91		
906	80-30-F	66	47	113	75.77	16.54	1.11	6.58	1.00		
908	120-20-F	101	23	124	76.98	15.96	1.04	6.02	0.91		
910	120-25-F	236	15	251	76.98	15.96	1.04	6.02	0.91		
912	120-30-F	110	153	263	76.45	15.92	1.35	6.28	0.67		
913	160-15-F	98	43	141	75.87	16.14	2.72	5.27	0.91		
914	160-20-F	194	47	241	75.87	16.14	2.72	5.27	0.91		
916	160-25-F	302	128	430	75.87	16.14	2.72	5.27	0.91		
917	160-27-F	492	140	632	76.98	15.96	1.04	6.02	0.91		
918	160-30-F	987	238	1225	76.98	15.96	1.04	6.02	0.91		
920	200-20-F	204	85	289	75.87	16.14	2.72	5.27	0.91		
922	200-25-F	316	208	524	76.45	15.92	1.35	6.28	0.67		
923	240-15-F	508	84	592	75.77	16.54	1.11	6.58	1.00		
924	240-20-F	514	95	609	75.77	16.54	1.11	6.58	1.00		
927	280-15-F	584	58	642	75.77	16.54	1.11	6.58	1.00		
929	320-15-F	——	——	——	——	——	——	——	——	——	——

Test Number	Laboratory Designation	Calorific Value Per Lb. of Fuel, B. T. U.					Analysis of Smoke-Box Gases Per Cent.					
		Of Dry Coal	Of Combustible	Of Cinders	Of Sparks		Oxygen O	Carbon Monoxide CO	Carbon Dioxide CO_2	Nitrogen N		
		248	249	250	251	252	253	254	255	256	257	258
901	80-15-F	15264	16138	11713	10868		9.26	0	10.46	80.26		
902	80-20-F	15077	16221	10370	11784		8.40	0	10.67	80.93		
904	80-25-F	15167	16128	12491	11784		11.80	0	7.80	80.30		
906	80 30-F	15020	16090	11291	10065		8.53	0	9.67	81.80		
908	120-20-F	15167	16128	10606	8484		8.70	0	10.50	80.80		
910	120-25-F	15167	16128	11194	11017		5.40	0	13.60	80.90		
912	120-30-F	15057	16079	11998	12057		6.86	0	11.33	81.80		
913	160-15-F	15264	16138	12770	8910		6.86	0.13	12.20	80.80		
914	160-20-F	15264	16138	11048	9860		10.30	0	9.06	80.60		
916	160-25-F	15264	16138	9287	9042		9.73	.06	9.60	80.60		
917	160-27-F	15167	16128	9701	11617		2.60	.06	14.40	82.40		
918	160-30-F	15167	16128	11497	10899		4.70	.06	12.70	82.00		
920	200-20-F	15264	16138	9471	11378		9.13	.06	10.33	80.46		
922	200-25-F	15057	16079	11523	11198		6.60	1.20	10.20	82.00		
923	240-15-F	15020	16090	10506	9799		5.20	1.60	11.00	82.20		
924	240-20-F	15020	16090	12157	11977		6.40	0.20	11.00	82.40		
927	280-15-F	15020	16090	11472	12197		5.60	2.00	10.60	81.80		
929	320-15-F	——	——	——	——		——	——	——	——		

SUMMARY OF AVERAGE RESULTS—LOCOMOTIVE No. 5266.
PENNSYLVANIA RAILROAD COMPANY.

Test Number	Laboratory Designation	Water, in Pounds						Dynamometer		
			Lost					Draw-Bar Pull in Pounds		
		Delivered to Injectors	From Boiler	From Injectors	From	Total	Delivered to Boiler and Presumably Evaporated	Average	Maximum	Minimum
		259	260	261	262	263	264	265	266	267
901	80-15-F	44020	0	0		0	44020	6427	6621	6111
902	80-20-F	48226	0	0		0	48226	7653	7952	7395
904	80-25-F	56041	0	505		505	55536	9810	10441	9603
906	80-30-F	67608	0	0		0	67608	12475	13147	12036
908	120-20-F	60685	0	279		279	60406	7280	7858	6716
910	120-25-F	70109	0	108		108	70001	9438	9638	9213
912	120-30-F	69278	0	0		0	69278	11785	12320	10976
913	160-15-F	62596	0	0		0	62596	5578	5782	5169
914	160-20-F	66120	0	0		0	66120	6538	7300	6146
916	160-25-F	66090	0	0		0	66090	8155	8510	7992
917	160-27-F	86070	0	60		60	86010	8757	9493	7525
918	160-30-F	30721	0	0		0	30721	9571	10149	9008
920	200-20-F	65283	0	0		0	65283	6199	6462	5960
922	200-25-F	36360	0	0		0	36360	7701	8022	7390
923	240-15-F	41048	0	0		0	41048	4940	5204	4460
924	240-20-F	28670	0	0		0	28670	5908	6141	5436
927	280-15-F	28890	0	0		0	28890	4752	5061	4360
929	320-15-F	——	——	——	——	——	——	4424	——	——

Test Number	Laboratory Designation	Events of Stroke from Indicator Cards											
		Cut-off, Per Cent. of Stroke								Release, Per Cent. of Stroke			
		High Pressure Cylinder				Low Pressure Cylinder				High Pressure Cylinder			
		Right Side		Left Side		Right Side		Left Side		Right Side		Left Side	
		Head End	Crank End	Head End	Crank End	Head End	Crank End	Head End	Crank End	Head End	Crank End	Head End	Crank End
		268	269	270	271	272	273	274	275	276	277	278	279
901	80-15-F	15.4	17.4	15.5	14.7					54.9	52.5	56.1	50.3
902	80-20-F	17.2	20.3	17.2	16.7					58.1	56.0	59.3	53.2
904	80-25-F	24.3	24.6	23.4	22.6					62.8	61.4	65.9	60.1
906	80-30-F	29.8	29.5	30.5	28.9					70.4	65.3	74.5	64.7
908	120-20-F	19.1	20.4	18.4	17.4					60.5	56.5	60.0	53.7
910	120-25-F	26.4	26.0	24.1	23.0					65.3	61.8	65.5	58.7
912	120-30-F	31.2	34.3	31.0	30.2					68.7	65.5	69.4	64.1
913	160-15-F	15.9	18.9	16.8	15.2					54.4	52.3	55.1	48.8
914	160-20-F	18.9	21.3	20.9	19.7					58.5	56.2	63.0	53.9
916	160-25-F	23.0	26.9	24.9	24.6					61.3	59.9	64.5	58.6
917	160-27-F	29.9	27.9	26.8	26.0					67.7	64.7	68.5	63.1
916	160-30-F	33.4	33.6	29.7	29.4					70.1	67.9	69.2	65.0
920	200-20-F	19.3	19.0	20.2	19.3					59.7	57.3	57.5	55.4
922	200-25-F	24.6	27.0	25.3	25.2					64.9	64.1	66.4	61.8
923	240-15-F	18.5	20.1	19.4	17.8					58.9	54.3	58.0	52.7
924	240-20-F	21.9	24.0	20.7	19.7					59.9	58.0	60.4	53.1
927	280-15-F	19.2	22.1	18.6	19.7					57.1	54.1	58.1	53.7
929	320-15-F	22.0	21.7	20.3	21.7					59.5	52.7	62.0	54.1

SUMMARY OF AVERAGE RESULTS—LOCOMOTIVE No. 5266.

PENNSYLVANIA RAILROAD COMPANY.

Test Number	Laboratory Designation	Events of Stroke from Indicator Cards											
		Release, Per Cent. of Stroke				Beginning of Compression, Per Cent. of Stroke							
		Low Pressure Cylinder				High Pressure Cylinder				Low Pressure Cylinder			
		Right Side		Left Side		Right Side		Left Side		Right Side		Left Side	
		Head End	Crank End	Head End	Crank End	Head End	Crank End	Head End	Crank End	Head End	Crank End	Head End	Crank End
		280	281	282	283	284	285	286	287	288	289	290	291
901	80-15-F					45.1	39.0	46.6	39.1				
902	80-20-F					39.6	37.8	42.7	38.4				
904	80-25-F					36.2	31.8	38.2	32.5				
906	80-30-F					33.1	25.6	32.4	27.7				
908	120-20-F					40.3	36.6	42.7	36.9				
910	120-25-F					35.0	31.6	37.6	31.7				
912	120-30-F					32.4	34.3	32.3	30.2				
913	160-15-F					43.1	40.4	45.5	38.9				
914	160-20-F					41.8	38.0	43.1	37.6				
916	160-25-F					36.2	33.8	37.9	32.7				
917	160-27-F					32.3	29.7	35.2	28.5				
918	160-30-F					29.6	27.9	23.6	26.9				
920	200-20-F					41.5	35.9	42.1	37.7				
922	200-25-F					33.8	30.9	35.2	29.9				
923	240-15-F					45.9	36.9	43.9	39.4				
924	240-20-F					39.7	35.6	40.7	40.1				
927	280-15-F					44.6	38.9	42.7	39.5				
929	320-15-F					43.0	38.3	43.0	38.3				

Test Number	Laboratory Designation	Pressure from Indicator Cards								Factor of Evaporation
		Initial Pressures, Pounds Per Square Inch								
		High Pressure Cylinder				Low Pressure Cylinder				
		Right Side		Left Side		Right Side		Left Side		
		Head End	Crank End	Head End	Crank End	Head End	Crank End	Head End	Crank End	
		292	293	294	295	296	297	298	299	300
901	80-15-F	180.9	198.4	193.4	192.1					1.2261
902	80-20-F	182.7	195.7	190.6	193.4					1.2276
904	80-25-F	192.9	187.4	188.9	189.7					1.2257
906	80-30-F	198.0	198.6	198.0	202.4					1.2346
908	120-20-F	180.8	181.0	184.8	185.0					1.2256
910	120-25-F	182.7	183.1	188.1	186.0					1.2263
912	120-30-F	177.2	194.1	192.5	186.6					1.2324
913	160-15-F	176.5	195.9	188.2	178.2					1.2286
914	160-20-F	173.4	195.7	188.7	178.6					1.2310
916	160-25-F	176.6	196.6	191.6	181.6					1.2320
917	160-27-F	180.0	178.2	186.5	179.0					1.2257
918	160-30-F	173.5	176.5	180.8	180.8					1.2220
920	200-20-F	181.7	197.3	195.9	186.8					1.2318
922	200-25-F	179.8	196.1	190.3	181.1					1.2327
923	240-15-F	182.0	191.0	196.0	192.0					1.2330
924	240-20-F	178.6	182.1	188.4	191.3					1.2335
927	280-15-F	186.9	194.8	185.4	192.4					1.2325
929	320-15-F	197.5	190.8	200.8	190.8					

SUMMARY OF AVERAGE RESULTS—LOCOMOTIVE No. 5266.

PENNSYLVANIA RAILROAD COMPANY.

Test Number	Laboratory Designation	Pressures from Indicator Cards								
		Steam Chest Pressures, Pounds Per Square Inch					Pressures at Cut-off, Pounds Per Square Inch			
		High Pressure		Low Pressure			High Pressure Cyinder			
							Right Side		Left Side	
		Right Side	Left Side	Right Side	Left Side		Head End	Crank End	Head End	Crank End
		301	302	303	304	305	306	307	308	309
901	80-15-F	198.3					148.8	169.4	164.5	163.2
902	80-20-F	196.7					158.1	165.4	167.7	166.4
904	80-25-F	196.5					166.9	171.6	156.4	170.3
906	80-30-F						173.8	176.1	174.2	178.2
908	120-20-F	197.2					154.4	152.7	151.5	164.0
910	120-25-F	196.3					148.3	159.1	154.7	161.6
912	120-30-F	198.6					146.0	164.1	156.1	168.5
913	160-15-F	198.0					123.8	145.9	135.0	136.9
914	160-20-F	202.0					124.1	146.1	128.8	127.3
916	160-25-F	202.0					127.5	146.0	135.9	138.4
917	160-27-F	187.2					131.7	130.2	136.0	138.9
918	160-30-F	185.5					125.2	137.8	135.4	141.1
920	200-20-F	197.1					121.2	145.6	129.8	129.5
922	200-25-F	203.0					123.4	139.0	134.1	125.8
923	240-15-F	——					115.0	126.0	127.0	128.0
924	240-20-F	——					108.8	126.7	127.1	133.4
927	280-15-F	——					109.3	118.9	115.3	115.9
929	320-15-F	——					106.7	112.5	112.9	113.3

Test Number	Laboratory Designation	Pressures from Indicator Cards											
		Pressures at Cut-off, Pounds Per Square Inch				Pressures at Release, Pounds Per Square Inch							
		Low Pressure Cylinder				High Pressure Cylinder				Low Pressure Cylinder			
		Right Side		Left Side		Right Side		Left Side		Right Side		Left Side	
		Head End	Crank End	Head End	Crank End	Head End	Crank End	Head End	Crank End	Head End	Crank End	Head End	Crank End
		310	311	312	313	314	315	316	317	318	319	320	321
901	80-15-F					56.8	72.6	58.0	64.6				
902	80-20-F					61.0	71.6	59.6	69.1				
904	80-25-F					64.9	74.9	65.6	68.6				
906	80-30-F					85.2	92.0	80.7	90.1				
908	120-20-F					57.1	66.4	55.2	63.8				
910	120-25-F					63.2	71.7	64.2	71.4				
912	120-30-F					72.5	89.0	72.9	85.0				
913	160-15-F					48.8	61.3	50.5	55.6				
914	160-20-F					46.7	62.7	54.4	53.3				
916	160-25-F					55.4	71.8	58.9	63.0				
917	160-27-F					60.2	61.7	58.1	62.6				
918	160-30-F					61.0	69.3	60.8	66.0				
920	200-20-F					47.7	58.1	53.0	53.1				
922	200-25-F					54.9	64.4	56.1	57.5				
923	240-15-F					45.0	57.0	50.0	51.0				
924	240-20-F					48.3	59.3	51.3	56.9				
927	280-15-F					45.5	54.9	43.9	47.6				
929	320-15-F					46.7	53.3	42.4	50.0				

SUMMARY OF AVERAGE RESULTS—LOCOMOTIVE No 5266.
PENNSYLVANIA RAILROAD COMPANY.

Test Number	Laboratory Designation	Pressures from Indicator Cards.											
		Pressures at Beginning of Compression, Pounds Per Square Inch								Least Back Pressure, Pounds Per Square Inch			
		High Pressure Cylinder				Low Pressure Cylinder				High Pressure Cylinder			
		Right Side		Left Side		Right Side		Left Side		Right Side		Left Side	
		Head End	Crank End	Head End	Crank End	Head End	Crank End	Head End	Crank End	Head End	Crank End	Head End	Crank End
		322	323	324	325	326	327	328	329	330	331	332	333
901	80-15-F	2.7	3.1	2.5	2.3					1.9	1.9	1.8	1.2
902	80-20-F	1.7	.9	2.8	1.9					1.1	.4	1.9	1.1
904	80-25-F	2.8	2.7	3.5	2.7					2.3	2.0	3.2	1.8
906	80-30-F	1.9	3.3	2.5	2.0					1.7	3.0	2.2	1.7
908	120-20-F	6.1	5.3	4.6	4.6					5.5	3.3	3.6	3.3
910	120-25-F	6.3	4.9	5.7	5.2					6.3	4.1	4.8	4.2
912	120-30-F	4.6	4.1	5.1	4.4					3.0	2.3	3.8	2.4
913	160-15-F	4.5	4.5	4.2	4.8					2.5	2.2	2.2	2.1
914	160-20-F	3.7	4.1	3.9	3.9					2.0	2.6	2.1	2.0
916	160-25-F	4.9	5.5	5.0	5.0					2.9	3.3	3.1	1.4
917	160-27-F	8.2	8.7	8.4	7.8					5.9	5.6	4.2	4.9
918	160-30-F	8.2	8.7	8.0	8.8					6.5	6.8	5.0	5.6
920	200-20-F	6.6	6.8	6.1	6.9					3.7	3.9	3.1	3.2
922	200-25-F	8.9	9.3	9.5	9.5					5.5	6.6	5.8	4.6
923	240-15-F	9.4	9.7	9.6	9.9					3.9	4.7	4.4	3.7
924	240-20-F	10.0	10.0	10.0	10.4					4.8	6.3	7.1	5.3
927	280-15-F	10.1	11.7	11.3	10.4					4.1	5.9	3.9	3.6
929	320-15-F	13.7	10.8	13.8	13.3					4.2	6.3	4.2	4.2

Test Number	Laboratory Designation	Pressures from Indicator Cards				Boiler					
		Least Back Pressure, Pounds Per Sq. Inch				Dry Coal Fired, Pounds		Evaporation, Pounds			
		Low Pressure Cylinder						Steam Per Hour			
		Right Side		Left Side							
		Head End	Crank End	Head End	Crank End	Per Hour	Per Sq. Ft. of Grate Surface	Moist	Dry	Dry, Per Sq. Ft. of Heating Surface	Dry Steam Per Pound of Dry Coal Fired
		334	335	336	337	338	339	340	341	342	343
901	80-15-F					1665	30.00	14673	14523	6.26	8.72
902	80-20-F					1934	34.85	16075	15922	6.87	8.23
904	80-25-F					2177	39.23	18512	18329	7.90	8.42
906	80-30-F					2932	52.83	22536	22290	9.61	7.60
908	120-20-F					2455	44.24	20135	19936	8.60	8.12
910	120-25-F					3333	60.04	23334	23102	9.96	6.93
912	120-30-F					3988	71.86	27711	27420	11.82	6.88
913	160-15-F					2729	49.17	20759	20559	8.86	7.53
914	160-20-F					2998	54.01	22040	21813	9.41	7.28
916	160-25-F					4221	76.05	26436	26174	11.29	6.20
917	160-27-F					4802	86.53	28670	28386	12.24	5.91
918	160-30-F					5581	100.58	30721	30417	13.11	5.45
920	200-20-F					3694	66.56	26113	25849	11.15	7.00
922	200-25-F					4983	89.78	30300	30000	12.93	6.02
923	240-15-F					5080	91.53	27365	27075	11.67	5.33
924	240-20-F					6101	109.93	28670	28386	12.24	4.65
927	280-15-F					5012	90.31	28890	28592	12.33	5.70
929	320-15-F					—	—	—	—	—	—

SUMMARY OF AVERAGE RESULTS—LOCOMOTIVE No. 5266.
PENNSYLVANIA RAILROAD COMPANY.

Test Number	Laboratory Designation	Boiler: Equiv't Evap'n from and at 212° F., Pounds: Per Hour	Per Hour Per Sq. Ft. of Heat. Surface	Per Pound of Coal as Fired	Per Pound of Dry Coal as Fired	Per Pound of Com-bustible	Boiler Horse Power	Efficiency of Boiler	Engines: Mean Effective Pressure, Pounds Per Square Inch, High Pressure Cylinder, Right Side: Head End	Right Side: Crank End	Left Side: Head End	Left Side: Crank End
		344	345	346	347	348	349	350	351	352	353	354
901	80-15-F	17806	7.68	10.40	10.69	11.31	516.0	67.65	55.70	67.50	59.20	59.83
902	80-20-F	19546	8.43	9.99	10.11	10.88	566.6	64.76	65.79	74.64	68.41	66.40
904	80-25-F	22466	9.69	10.21	10.32	10.98	651.1	65.71	86.90	86.30	81.60	83.07
906	80-30-F	27519	11.87	9.28	9.39	10.05	797.7	60.38	103.49	105.12	105.18	105.85
908	120-20-F	24434	10.54	9.85	9.95	10.58	708.2	63.36	67.70	68.90	63.20	64.70
910	120-25-F	28330	12.21	8.40	8.50	9.03	821.2	54.13	81.90	84.30	80.40	80.70
912	120-30-F	33792	14.68	8.36	8.47	9.05	979.4	54.32	90.61	104.80	95.76	99.36
913	160-15-F	25259	10.89	9.00	9.26	9.79	732.1	58.59	49.65	61.62	53.51	51.29
914	160-20-F	26851	11.58	8.70	8.96	9.46	778.3	56.68	53.36	68.56	59.44	57.17
916	160-25-F	32246	13.90	7.43	7.64	8.08	934.7	48.34	65.95	81.04	72.16	72.68
917	160-27-F	34793	15.00	7.17	7.25	7.70	1008.5	46.17	78.31	75.64	74.12	76.08
918	160-30-F	37170	16.03	6.59	6.66	7.08	1077.4	42.41	81.07	85.95	78.44	81.48
920	200-20-F	31841	13.73	8.38	8.62	9.11	922.9	54.52	54.83	64.26	58.84	57.20
922	200-25-F	36981	15.94	7.32	7.42	7.93	1071.9	47.59	66.33	77.33	70.90	67.81
923	240-15-F	33383	14.39	6.50	6.57	7.04	967.6	42.25	46.02	57.53	52.97	52.18
924	240-20-F	35014	15.10	5.68	5.74	6.15	1014.9	36.91	49.69	61.68	56.30	56.25
927	280-15-F	35240	15.19	6.95	7.03	7.53	1021.4	45.20	45.71	53.67	47.94	46.93
929	320-15-F	——	——	——	——	——	——	——	43.32	49.63	44.75	47.02

Test Number	Laboratory Designation	Engines: Mean Effective Pressure, Pounds Per Sq. Inch, Low Pressure Cylinder, Right Side: Head End	Right Side: Crank End	Left Side: Head End	Left Side: Crank End	Receiver Pressure: Right Side	Receiver Pressure: Left Side	Number of Expansions, Right Side: Head End	Right Side: Crank End	Left Side: Head End	Left Side: Crank End
		355	356	357	358	359	360	361	362	363	364
901	80-15-F							2.41	2.19	2.46	2.34
902	80-25-F							2.37	2.10	2.42	2.28
904	80-25-F							2.04	2.00	2.19	2.09
906	80-30-F							1.96	1.86	2.03	1.88
908	120-20-F							2.30	2.11	2.35	2.24
910	120-25-F							1.99	1.94	2.13	2.02
912	120-30-F							1.85	1.67	1.88	1.81
913	160-15-F							2.34	2.08	2.24	2.24
914	160-20-F							2.25	2.05	2.26	2.08
916	160-25-F							2.07	1.85	2.06	1.93
917	160-27-F							1.89	1.92	2.06	1.98
918	160-30-F							1.79	1.75	1.93	1.86
920	200-20-F							2.26	2.23	2.14	2.15
922	200-25-F							2.08	1.95	2.09	1.99
923	240-15-F							2.29	2.06	2.21	2.18
924	240-20-F							2.10	1.94	2.20	2.06
927	280-15-F							2.19	1.94	2.27	2.08
929	320-15-F							——	——	——	——

SUMMARY OF AVERAGE RESULTS—LOCOMOTIVE No. 5266.
PENNSYLVANIA RAILROAD COMPANY.

Test Number	Laboratory Designation	Engines. Indicated Horse Power. High Pressure Cylinder. Right Side. Head End	Crank End	Left Side. Head End	Crank End	Low Pressure Cylinder. Right Side. Head End	Crank End	Left Side. Head End	Crank End	Division of Power. High Pressure Cylinder. Right Side	Left Side	Low Pressure Cylinder. Right Side	Left Side
		365	366	367	368	369	370	371	372	373	374	375	376
901	80-15-F	96.6	113.7	105.7	103.8					210.3	209.5		
902	80-20-F	114.1	125.8	122.1	115.2					239.9	237.3		
904	80-25-F	150.7	145.4	145.4	144.1					296.1	289.5		
906	80-30-F	179.5	177.1	187.7	183.6					356.6	371.3		
908	120-20-F	176.0	174.1	169.2	168.3					350.1	337.5		
910	120-25-F	213.0	213.0	215.2	209.9					426.0	425.1		
912	120-30-F	235.7	264.8	256.4	258.5					500.5	514.9		
913	160-15-F	172.3	207.6	191.0	177.9					379.9	368.9		
914	160-20-F	185.1	231.1	212.2	198.4					416.2	410.6		
916	160-25-F	228.8	273.1	257.6	252.1					501.9	509.7		
917	160-27-F	271.6	254.9	264.6	263.9					526.5	528.5		
918	160-30-F	281.2	289.6	279.9	282.6					570.8	562.6		
920	200-20-F	237.4	270.7	262.5	248.0					508.1	510.5		
922	200-25-F	287.6	325.7	316.4	294.0					613.3	610.4		
923	240-15-F	239.5	290.8	283.6	271.5					530.3	555.1		
924	240-20-F	258.5	311.8	301.5	292.7					570.3	594.2		
927	280-15-F	277.5	316.5	299.5	284.9					594.0	584.4		
929	320-15-F	300.7	334.6	319.6	326.4					635.3	646.0		

Test Number	Laboratory Designation	Engines. Division of Power. Total. Right Side	Left Side	Total I. H. P.	Consumed Per I. H. P., Per Hour. Dry Coal, Pounds	Dry Steam, Pounds	B. T. U.	Locomotive. Dynamometer Horse Power	Pounds Per D. H. P., Per Hour. Of Dry Coal	Of Dry Steam	B. T. U. Per D. H. P., Per Hour
		377	378	379	380	381	382	383	384	385	386
901	80-15-F	210.3	209.5	419.8	3.97	33.54	60598	327.3	5.09	43.02	77693
902	80-20-F	239.9	237.3	477.2	4.05	32.27	61069	389.8	4.96	39.50	74782
904	80-25-F	296.1	289.5	585.6	3.72	30.65	56480	499.6	4.36	35.92	66128
906	80-30-F	356.6	371.3	727.9	4.03	29.94	60531	632.3	4.64	34.46	69693
908	120-20-F	350.1	337.5	687.6	3.57	28.81	54160	556.2	4.42	35.16	67040
910	120-25-F	426.0	425.1	851.1	3.92	26.70	59450	721.1	4.62	31.51	70070
912	120-30-F	500.5	514.9	1015.4	3.93	26.63	59174	900.8	4.43	29.59	66702
913	160-15-F	379.9	368.9	748.8	3.64	26.75	55560	568.2	4.80	35.26	73267
914	160-20-F	416.2	410.6	826.8	3.63	25.34	55408	665.9	4.50	31.46	68680
916	160-25-F	501.9	509.7	1011.6	4.17	25.23	63650	830.7	5.08	30.73	77541
917	160-27-F	526.5	528.5	1055.0	4.55	26.50	68964	892.1	5.38	31.34	81640
918	160-30-F	570.8	562.6	1133.4	4.92	26.46	74622	975.0	5.72	30.83	86750
920	200-20-F	508.1	510.5	1018.6	3.63	24.83	55410	789.4	4.68	32.04	71435
922	200-25-F	613.3	610.4	1223.7	4.07	23.84	61280	980.6	5.08	29.75	76480
923	240-15-F	530.3	555.1	1085.4	4.68	24.60	70294	880.7	5.77	30.31	86665
924	240-20-F	570.3	594.2	1164.5	5.24	24.37	78705	902.8	6.76	31.43	101535
927	280-15-F	594.0	584.4	1178.4	4.25	23.81	63835	847.2	5.92	33.12	88918
929	320-15-F	635.3	646.0	1281.3	——	——	——	896.9	——	——	——

SUMMARY OF AVERAGE RESULTS—LOCOMOTIVE No. 5266.

PENNSYLVANIA RAILROAD COMPANY.

Test Number	Laboratory Designation	Locomotive: Per One Million Foot Pounds at Draw-Bar: Dry Coal, Pounds	Dry Steam, Pounds	B. T. U.	I. H. P., Per Square Foot of: Heating Surface	Grate Surface	D. H. P. Per Square Foot of: Heating Surface	Grate Surface	Tractive Power Based on M. E. P., Pounds	Machine Friction of Locomotive, in Terms of: Horse Power	M. E. P., Pounds	Draw-Bar Pull, Pounds
		387	388	389	390	391	392	393	394	395	396	397
901	80-15-F	2.57	21.73	39220	.181	7.56	.141	5.90	8240	92.5	13.34	1816
902	80-20-F	2.51	19.94	37843	.206	8.60	.168	7.02	9368	87.4	12.57	1716
904	80-25-F	2.20	18.15	33370	.253	10.55	.215	9.00	11510	86.0	12.40	1689
906	80-30-F	2.34	17.40	35147	.314	13.12	.273	11.39	14360	95.6	13.78	1886
908	120-20-F	2.23	17.74	33820	.296	12.39	.240	10.02	9000	131.4	12.63	1652
910	120-25-F	2.36	15.91	35799	.367	15.33	.311	12.99	11138	130.1	12.50	1702
912	120-30-F	2.24	14.95	33727	.438	18.29	.388	16.23	13291	114.6	11.01	1499
913	160-15-F	2.43	17.81	37091	.323	13.49	.245	10.23	7350	180.6	13.01	1417
914	160-20-F	2.27	15.88	34640	.357	14.90	.287	12.00	8115	160.9	11.60	1579
916	160-25-F	2.58	15.53	39230	.436	18.22	.358	14.97	9929	180.9	13.03	1775
917	160-27-F	2.72	15.83	41255	.455	19.01	.385	16.07	10354	162.9	11.74	1599
918	160-30-F	2.89	15.58	43860	.489	20.42	.420	17.57	11126	158.4	11.41	1554
920	200-20-F	3.63	16.18	55408	.439	18.35	.340	14.22	8000	229.2	13.21	1805
922	200-25-F	2.57	15.03	38698	.528	22.04	.423	17.66	9610	243.1	14.01	1909
923	240-15-F	3.40	17.86	51068	.468	19.56	.380	15.87	7103	204.7	8.43	1148
924	240-20-F	3.41	15.88	51218	.502	20.98	.389	16.27	7621	261.7	12.57	1713
927	280-15-F	2.99	16.73	44910	.508	21.23	.365	15.26	6610	331.2	13.64	1858
929	320-15-F	——	——	——	——	——	——	——	6316	——	——	——

Test Number	Laboratory Designation	Locomotive: Machine Efficienc of Locomotive, Per Cent	Efficiency of Locomotive, Per Cent.	Ratios: Total Weight of Locomotive to Maximum I. H. P.	Total Heating Surface to Maximum I. H. P.	Millions of Foot Lbs. at Draw-Bar Per Hour	Maximum I. H. P.				Date of Test
		398	399	400	401	402	403	404	405	406	407
901	80-15-F	77.96	3.28		5.39	648	429.7				12-28-06
902	80-20-F	81.68	3.40		4.66	772	497.7				1-15-07
904	80-25-F	85.35	3.85		3.73	989	622.2				11-20-06
906	80-30-F	86.87	3.65		3.07	1252	756.3				3- 4-07
908	120-20-F	80.89	3.79		3.26	1102	711.9				11-21-06
910	120-25-F	84.71	3.63		2.67	1427	867.8				11-22-06
912	120-30-F	88.71	3.82		2.21	1783	1048.5				12-15-06
913	160-15-F	75.88	3.47		3.05	1125	759.8				1- 3-07
914	160-20-F	80.54	3.71		2.75	1319	843.0				12-18-06
916	160-25-F	82.11	3.28		2.26	1644	1028.5				12-19-06
917	160-27-F	84.56	3.18		2.07	1766	1120.1				11-28-06
918	160-30-F	86.02	2.93		1.99	1930	1160.7				11-26-06
920	200-20-F	77.49	3.56		2.20	1563	1053.5				12-20-06
922	200-25-F	80.13	3.33		1.86	1941	1247.8				12-12-06
923	240-15-F	81.14	2.94		1.76	1495	1319.7				2-20-07
924	240-20-F	77.53	2.51		1.95	1787	1191.2				2-16-07
927	280-15-F	71.89	2.86		1.85	1677	1251.0				2-21-07
929	320-15-F	70.00	——		——	——	——				3- 7-07

SUMMARY OF AVERAGE RESULTS—LOCOMOTIVE No. 5266.

PENNSYLVANIA RAILROAD COMPANY.

Test Number	Laboratory Designation	Duration of Test Hours	Revolutions Per Minute	Equivalent Miles Per Hour	Approximate Cut-off, Per Cent. of Stroke, High Pressure Cylinder	Position of Throttle	Boiler Pressure, Lbs. Per Sq. In.	Br. Pipe Pressure Lbs. Per Sq. In.	Draft, Front of Diaphragm, Inches of Water	Dry Coal Fired Per Hour, Pounds	Dry Steam Used Per Hour, Pounds
		196	198	199	268 to 271	203	217	220	222	338	341
901	80-15-F	3.00	80.00	19.10	15.7	Full	201.3	198.3	2.0	1665	14523
902	80-20-F	3.00	80.00	19.10	17.9	Full	200.1	197.3	2.1	1934	15922
904	80-25-F	3.00	79.99	19.09	23.7	Full	198.5	192.8	3.3	2177	18329
906	80-30-F	3.00	80.00	19.01	29.7	Full	202.6	199.8	3.4	2932	22290
908	120-20-F	3.00	120.00	28.65	18.8	Full	201.0	197.7	3.9	2455	19936
910	120-25-F	3.00	120.00	28.65	24.9	Full	200.5	197.5	5.1	3333	23102
912	120-30-F	2.50	120.00	28.65	31.7	Full	202.7	197.8	4.9	3988	27420
913	160-15-F	3.00	160.00	38.20	16.7	Full	198.0	195.0	3.1	2729	20559
914	160-20-F	3.00	160.00	38.20	20.2	Full	202.9	198.2	3.7	2998	21813
916	160-25-F	2.50	160.00	38.20	24.9	Full	200.0	195.0	5.2	4221	26174
917	160-27-F	3.00	160.00	38.20	27.7	Full	188.4	185.6	7.7	4802	28386
918	160-30 F	1.00	160.00	38.20	31.5	Full	186.1	181.8	8.9	5581	30417
920	200-20-F	2.50	200.00	47.75	19.5	Full	202.0	197.4	5.0	3694	25849
922	200-25-F	1.20	200.00	47.75	25.5	Full	202.1	197.1	6.0	4983	30000
923	240-15-F	1.50	240.00	57.30	19.0	Full	196.4	194.2	5.6	5080	27075
924	240-20-F	1.00	240.00	57.30	21.6	Full	197.5	195.1	5.4	6101	28386
927	280-15-F	1.00	280.00	66.85	19.9	Full	194.4	191.7	5.6	5012	28592
929	320-15-F	——	320.17	76.08	21.4	Full	196.3	——	——	——	——

Test Number	Laboratory Designation	Equivalent Lbs. Water Per Lb. Coal from and at 212° F	Indicated Horse Power	Dynamometer Horse Power	Frictional Horse Power	Draw-Bar Pull, Pounds	Dry Coal Per I. H. P. Per Hour, Pounds	Dry Coal Per D. H. P. Per Hour, Pounds	Dry Steam Per I. H. P. Per Hour, Pounds	Dry Steam Per D. H. P. Per Hour, Pounds	Efficiency of Boiler	Efficiency of Locomotive
		347	379	383	395	265	380	384	381	385	350	399
901	80-15-F	10.69	419.8	327.3	92.5	6427	3.97	5.09	33.54	43.02	67.65	3.28
902	80-20-F	10.11	477.2	389.8	87.4	7653	4.05	4.96	32.27	39.50	64.76	3.40
904	80-25-F	10.32	585.6	499.6	86.0	9810	3.72	4.36	30.65	35.92	65.71	3.85
906	80-30-F	9.39	727.9	632.3	95.6	12475	4.03	4.64	29.94	34.46	60.38	3.65
908	120-20-F	9.95	687.6	556.2	131.4	7280	3.57	4.42	28.81	35.16	63.36	3.79
910	120-25-F	8.50	851.1	721.1	130.1	9438	3.92	4.62	26.70	31.51	54.13	3.63
912	120-30-F	8.47	1015.4	900.8	114.6	11785	3.93	4.43	26.63	29.59	54.32	3.82
913	160-15-F	9.26	748.8	568.2	180.6	5578	3.64	4.80	26.75	35.26	58.59	3.47
914	160-20-F	8.96	826.8	665.9	160.9	6538	3.63	4.50	25.34	31.46	56.68	3.71
916	160-25-F	7.64	1011.6	830.7	180.9	8155	4.17	5.08	25.23	30.73	48.34	3.28
917	160-27-F	7.25	1055.0	892.1	162.9	8757	4.55	5.38	26.50	31.34	46.17	3.18
918	160-30-F	6.66	1133.4	975.0	158.4	9571	4.92	5.72	26.46	30.83	42.41	2.93
920	200-20-F	8.62	1018.6	789.4	229.2	6199	3.63	4.68	24.83	32.04	54.52	3.56
922	200-25-F	7.42	1223.7	980.6	243.1	7701	4.07	5.08	23.84	29.75	47.59	3.33
923	240-15-F	6.57	1085.4	880.7	204.2	4940	4.68	5.77	24.60	30.31	42.25	2.94
924	240-20-F	5.74	1164.5	902.8	261.7	5908	5.24	6.76	24.37	31.43	36.91	2.51
927	280-15-F	7.03	1178.4	847.2	331.2	4752	4.25	5.92	23.81	33.12	45.20	2.86
929	320-15-F	——	1281.3	896.9	384.4	4424	——	——	——	——	——	——

GRAPHICAL LOG OF LOCOMOTIVE TEST

LOCOMOTIVE

TYPE 4-4-2

CLASS E 2 A

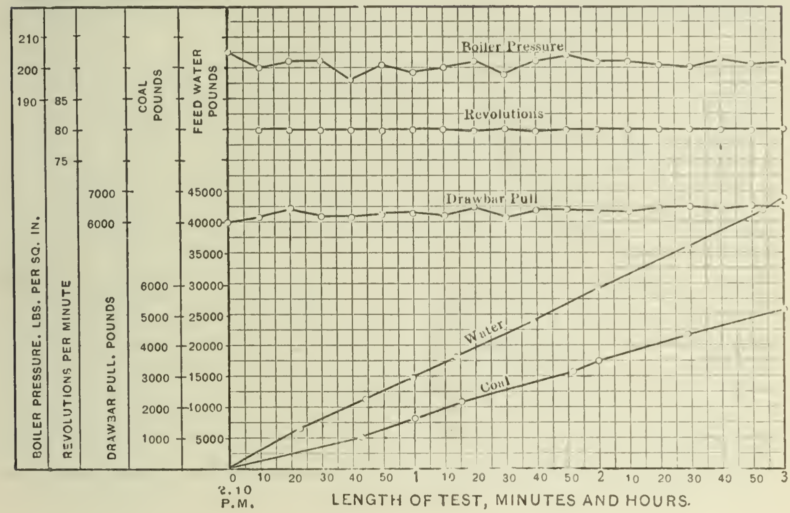
NUMBER 5266

SUBJECT: LOCOMOTIVE TEST WITH SCALP LEVEL COAL

TEST NO. 901

R.P.M.	CUT-OFF	THROTTLE
80	15	F

ALTOONA, PA. 12-28-'06



GRAPHICAL LOG OF LOCOMOTIVE TEST

LOCOMOTIVE

TYPE 4-4-2

CLASS E 2 A

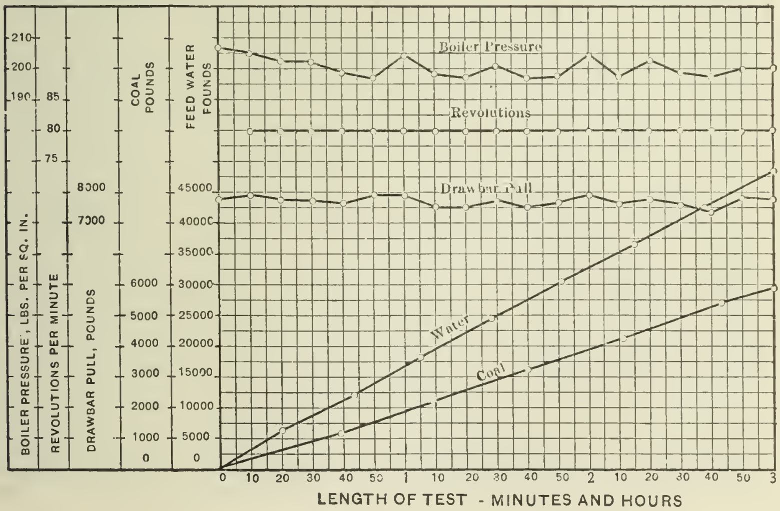
NUMBER 5266

SUBJECT: LOCOMOTIVE TEST WITH SCALP LEVEL COAL

TEST NO. 902

R.P.M.	CUT-OFF	THROTTLE
80	20	F

ALTOONA, PA. 1-15-07



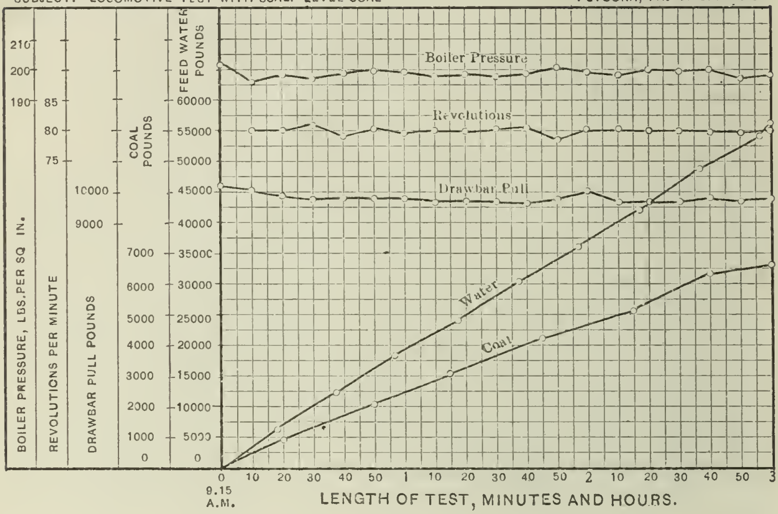
GRAPHICAL LOG OF LOCOMOTIVE TEST

LOCOMOTIVE
TYPE 4-4-2
CLASS E 2 A
NUMBER 5266

TEST NO. 904
R.P.M. 80 CUT-OFF 25 THROTTLE F.

SUBJECT: LOCOMOTIVE TEST WITH SCALP LEVEL COAL

ALTOONA, PA. 11-20-'06



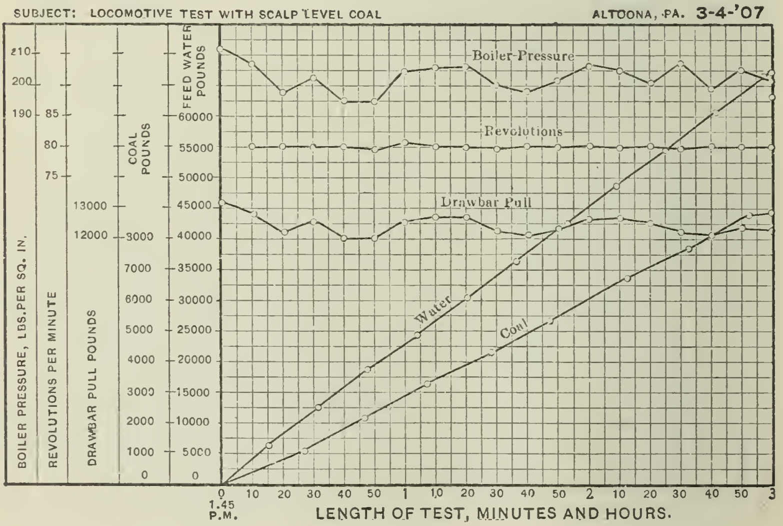
GRAPHICAL LOG OF LOCOMOTIVE TEST

LOCOMOTIVE
TYPE 4-4-2
CLASS E 2 A
NUMBER 5266

TEST NO. 906
R.P.M. 80 CUT-OFF 30 THROTTLE F.

SUBJECT: LOCOMOTIVE TEST WITH SCALP LEVEL COAL

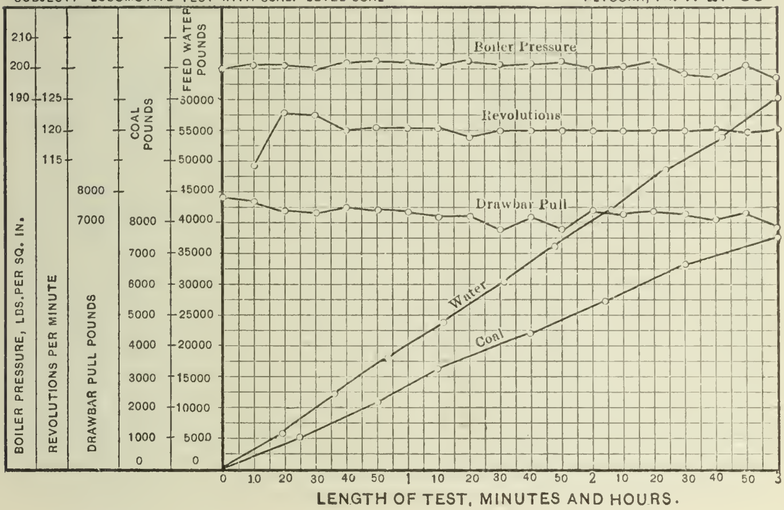
ALTOONA, PA. 3-4-'07



GRAPHICAL LOG OF LOCOMOTIVE TEST

LOCOMOTIVE
TYPE 4-4-2
CLASS E 2 A
NUMBER 5266
SUBJECT: LOCOMOTIVE TEST WITH SCALP LEVEL COAL

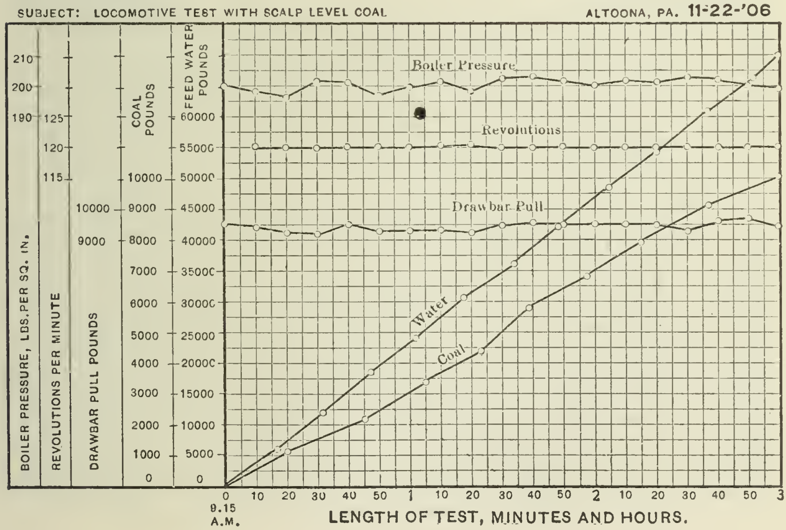
TEST NO. 908
R.P.M. 120 CUT-OFF 20 THROTTLE F.
ALTOONA, PA. 11-21-'06



GRAPHICAL LOG OF LOCOMOTIVE TEST

LOCOMOTIVE
TYPE 4-4-2
CLASS E 2 A
NUMBER 5266
SUBJECT: LOCOMOTIVE TEST WITH SCALP LEVEL COAL

TEST NO. 910
R.P.M 120 CUT-OFF 25 THROTTLE F.
ALTOONA, PA. 11-22-'06



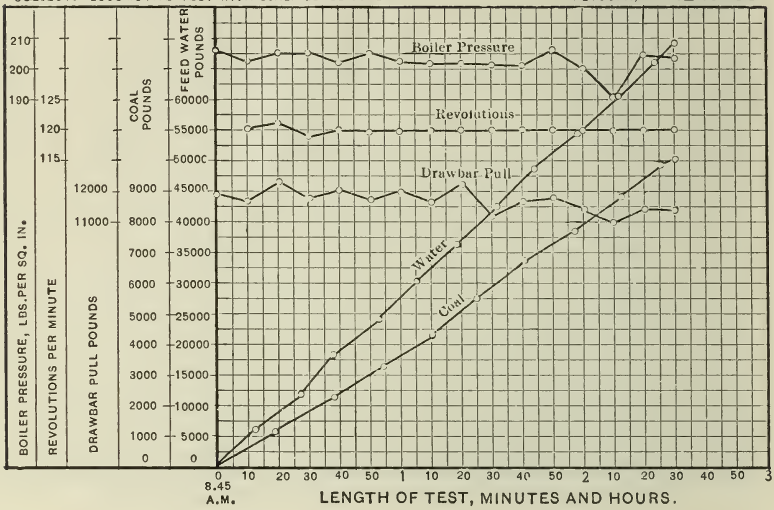
GRAPHICAL LOG OF LOCOMOTIVE TEST

LOCOMOTIVE
TYPE 4-4-2
CLASS E 2 A
NUMBER 5266

TEST NO. 912
R.P.M. 120 CUT-OFF 30 THROTTLE F.

SUBJECT: LOCOMOTIVE TEST WITH SCALP LEVEL COAL

ALTOONA, PA. 12-15-'06



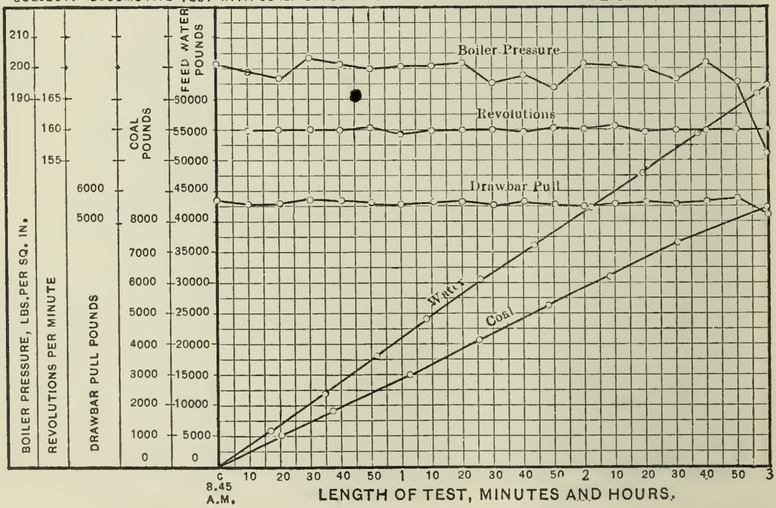
GRAPHICAL LOG OF LOCOMOTIVE TEST

LOCOMOTIVE
TYPE 4-4-2
CLASS E 2 A
NUMBER 5266

TEST NO. 913
R.P.M. 160 CUT-OFF 15 THROTTLE F.

SUBJECT: LOCOMOTIVE TEST WITH SCALP LEVEL COAL

ALTOONA, PA. 1-3-'07



GRAPHICAL LOG OF LOCOMOTIVE TEST

LOCOMOTIVE

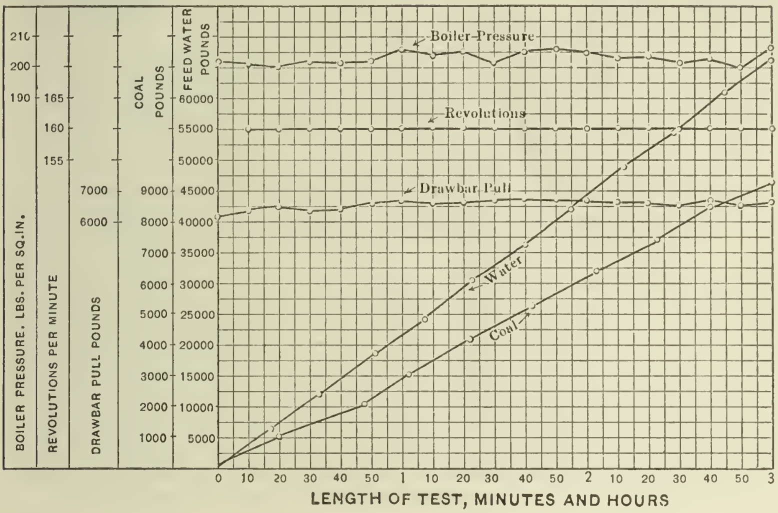
TYPE 4-4-2
CLASS E 2 A
NUMBER 5266

TEST NO. 914

R.P.M.	CUT-OFF	THROTTLE
160	20	F

SUBJECT: LOCOMOTIVE TEST WITH SCALP LEVEL COAL

ALTOONA PA. 12-18-'06



GRAPHICAL LOG OF LOCOMOTIVE TEST

LOCOMOTIVE

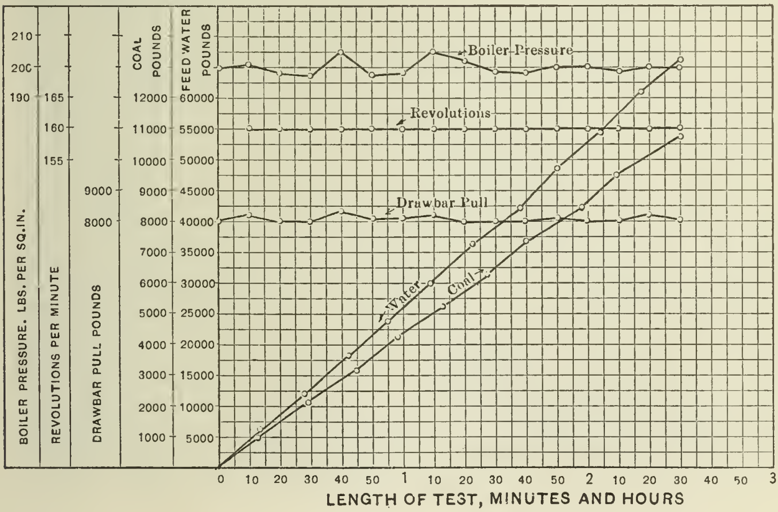
TYPE 4-4-2
CLASS E 2 A
NUMBER 5266

TEST NO. 916

R.P.M.	CUT-OFF	THROTTLE
160	25	F

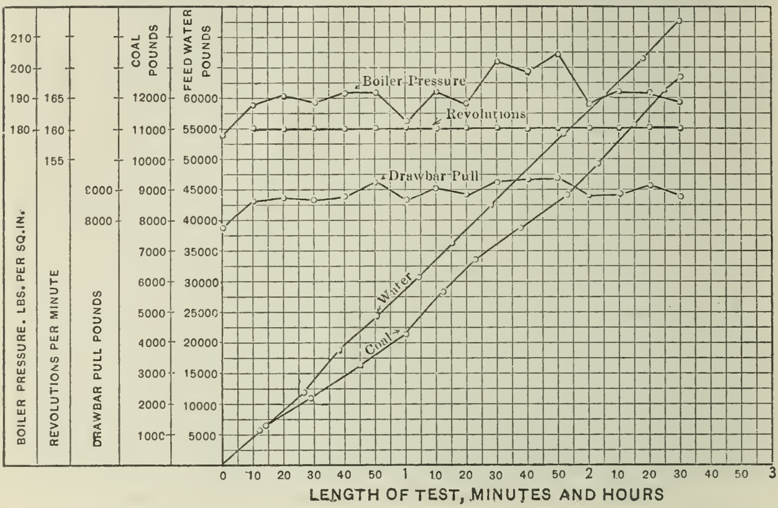
SUBJECT: LOCOMOTIVE TEST WITH SCALP LEVEL COAL

ALTOONA PA. 12-19-'06



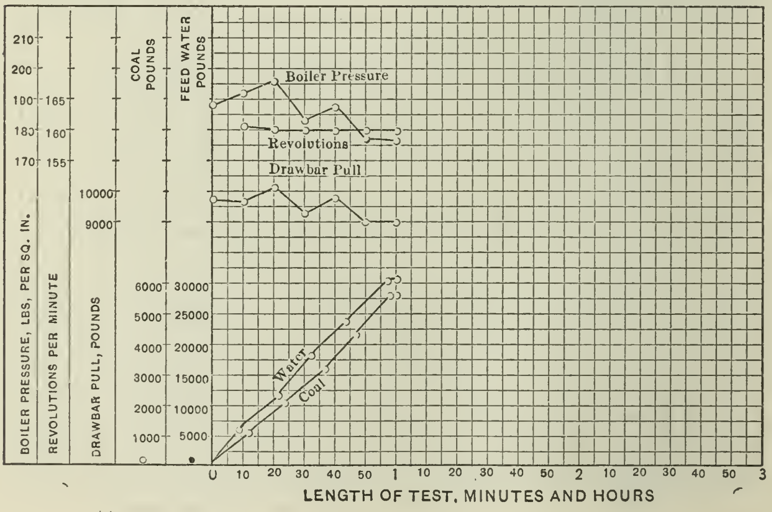
GRAPHICAL LOG OF LOCOMOTIVE TEST

LOCOMOTIVE | TEST NO. 917
TYPE 4-4-2 | R.P.M. 160 CUT-OFF 27 THROTTLE F
CLASS E 2 A
NUMBER 5266
SUBJECT: LOCOMOTIVE TEST WITH SCALP LEVEL COAL | ALTOONA PA. NOV.-28-'06



GRAPHICAL LOG OF LOCOMOTIVE TEST

LOCOMOTIVE | TEST NO. 918
TYPE 4-4-2 | R.P.M. 160 CUT-OFF 30 THROTTLE F
CLASS E 2 A
NUMBER 5266
SUBJECT: LOCOMOTIVE TEST WITH SCALP LEVEL COAL | ALTOONA, PA. 11-26-'06



GRAPHICAL LOG OF LOCOMOTIVE TEST

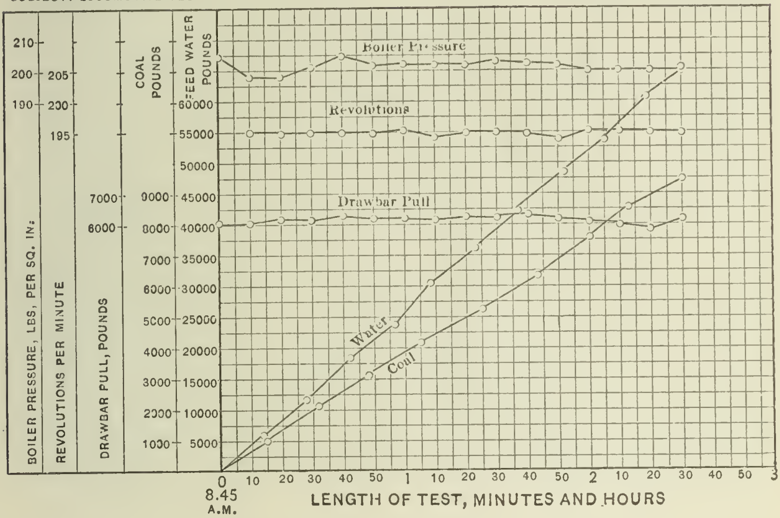
LOCOMOTIVE
TYPE 4-4-2
CLASS E 2A
NUMBER 5266

TEST NO 920

R.P.M.	CUT-OFF	THROTTLE
200	20	F

SUBJECT: LOCOMOTIVE TEST WITH SCALP LEVEL COAL

ALTOONA, PA. 12-20-'06



GRAPHICAL LOG OF LOCOMOTIVE TEST

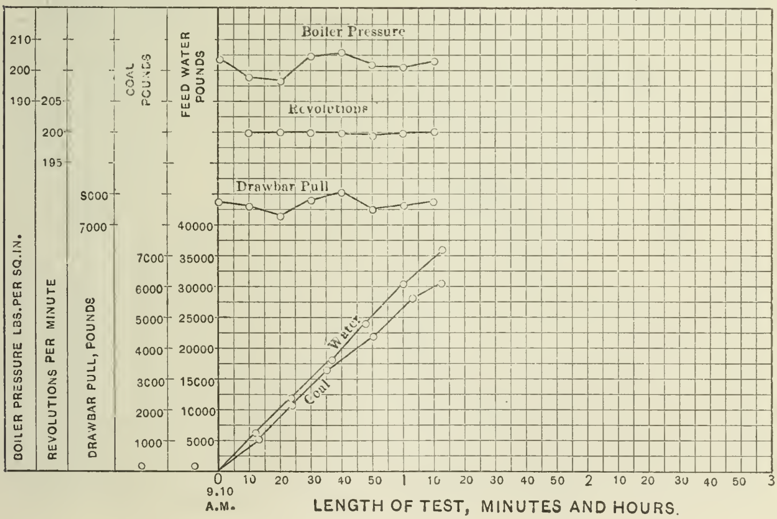
LOCOMOTIVE
TYPE 4-4-2
CLASS E 2A
NUMBER 5263

TEST NO. 922

R P.M.	CUT-OFF	THROTTLE
200	25	F

SUBJECT: LOCOMOTIVE TEST WITH SCALP LEVEL COAL.

ALTOONA, PA. 12-12-'06



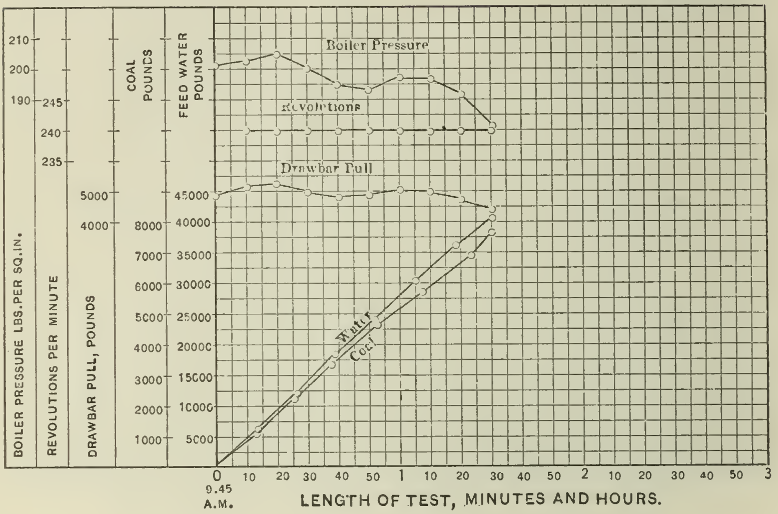
GRAPHICAL LOG OF LOCOMOTIVE TEST

LOCOMOTIVE
TYPE 4-4-2
CLASS E 2 A
NUMBER 5266

TEST NO. 923
R.P.M. CUT-OFF THROTTLE
240 15 F

SUBJECT: LOCOMOTIVE TEST WITH SCALP LEVEL COAL.

ALTOONA, PA. 2-20-'07



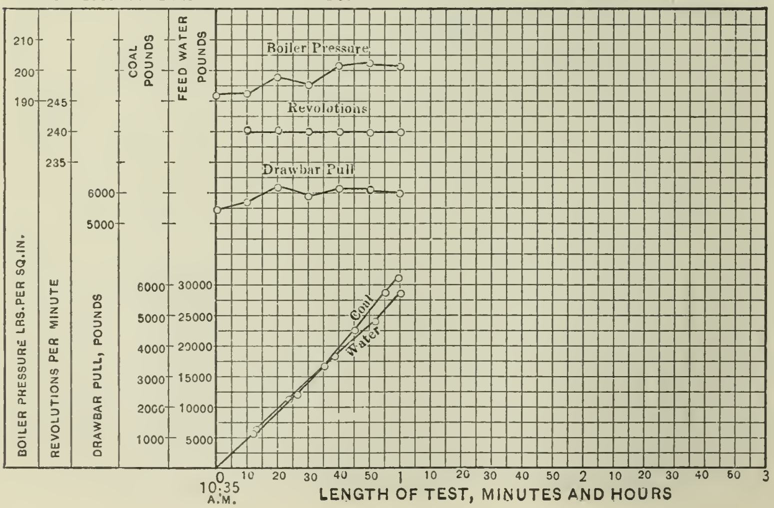
GRAPHICAL LOG OF LOCOMOTIVE TEST

LOCOMOTIVE
TYPE 4-4-2
CLASS E 2 A
NUMBER 5266

TEST NO. 924
R.P.M. CUT-OFF THROTTLE
240 20 F

SUBJECT: LOCOMOTIVE TEST WITH SCALP LEVEL COAL

ALTOONA, PA. 2-16-'07



GRAPHICAL LOG OF LOCOMOTIVE TEST

LOCOMOTIVE

TYPE 4-4-2

CLASS E 2 A

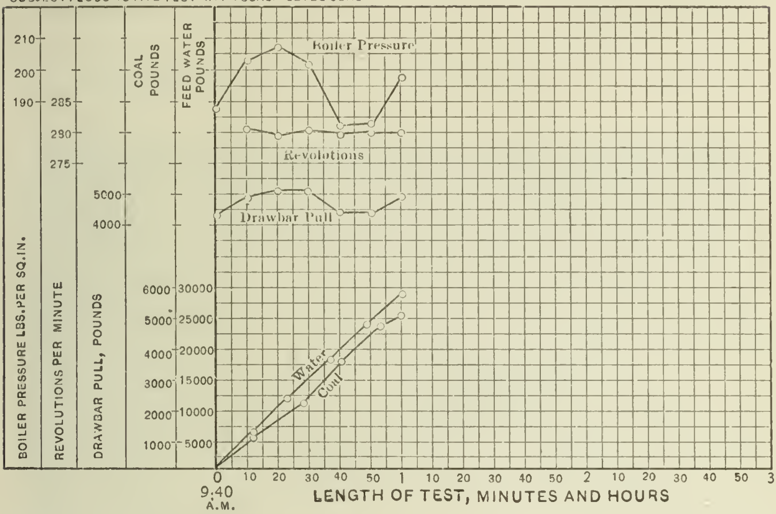
NUMBER 5266

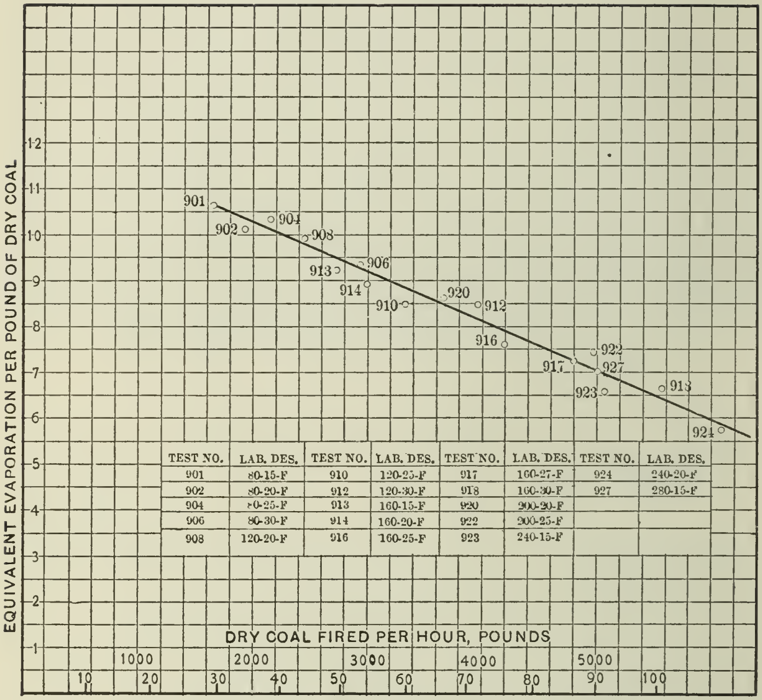
TEST NO. 927

R.P.M.	CUT-OFF	THROTTLE
280	15	F

SUBJECT: LOCOMOTIVE TEST WITH SCALP LEVEL COAL

ALTOONA, PA. 2-12-'07

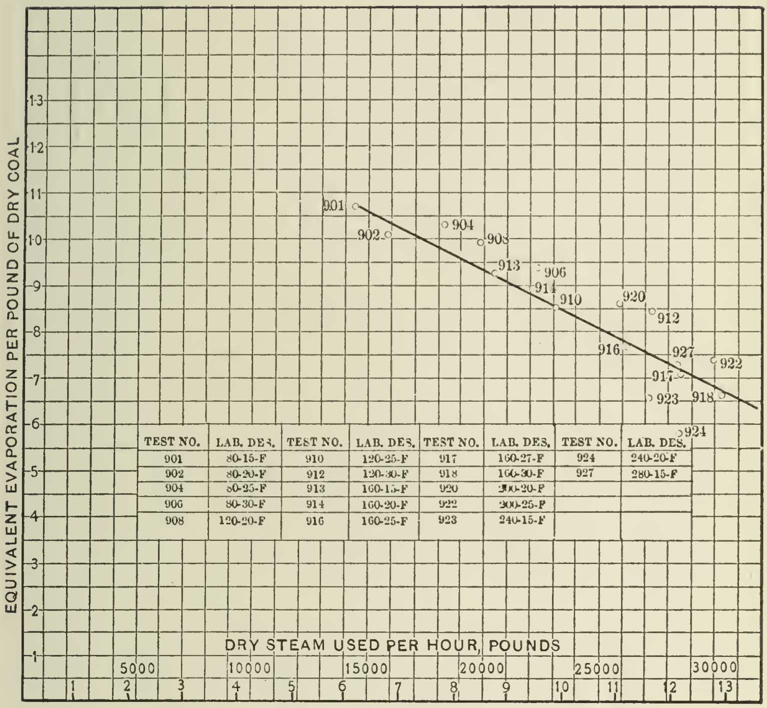




TEST NO.	LAB. DES.	TEST NO.	LAB. DES.	TEST NO.	LAB. DES.	TEST NO.	LAB. DES.
901	80-15-F	910	120-25-F	917	160-27-F	924	240-20-F
902	80-20-F	912	120-30-F	918	160-30-F	927	280-15-F
904	80-25-F	913	160-15-F	920	200-20-F		
906	80-30-F	914	160-20-F	922	200-25-F		
908	120-20-F	916	160-25-F	923	240-15-F		

DRY COAL FIRED PER HOUR, LBS. PER SQ. FOOT OF GRATE

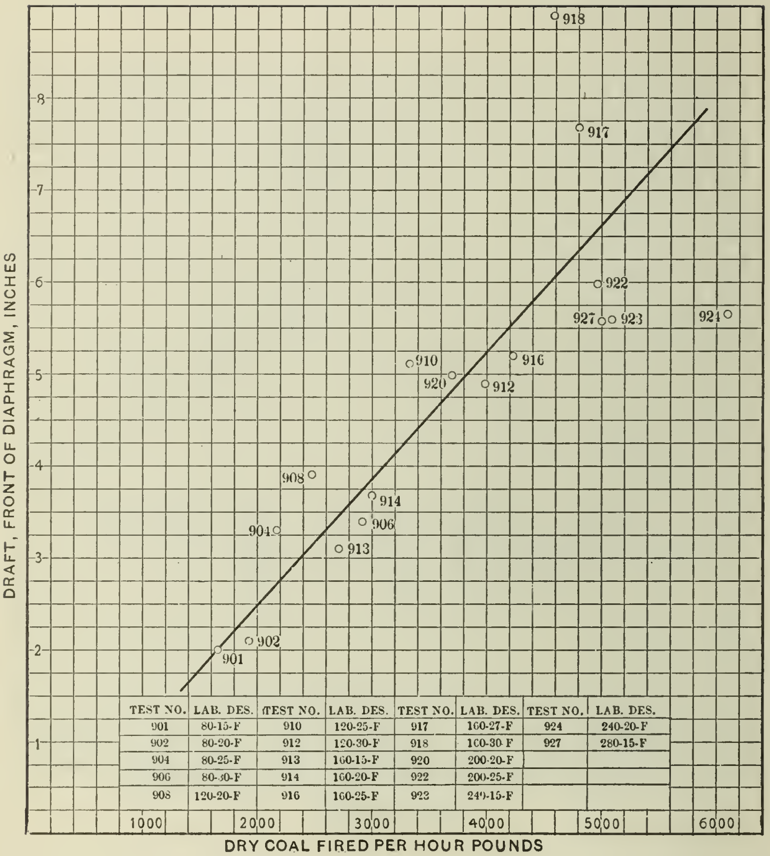
PLOT No. 901.



TEST NO.	LAB. DES.	TEST NO.	LAB. DES.	TEST NO.	LAB. DES.	TEST NO.	LAB. DES.
901	80-15-F	910	120-25-F	917	160-27-F	924	240-20-F
902	80-20-F	912	120-30-F	918	160-30-F	927	280-15-F
904	80-25-F	913	160-15-F	920	200-20-F		
906	80-30-F	914	160-20-F	922	200-25-F		
908	120-20-F	916	160-25-F	923	240-15-F		

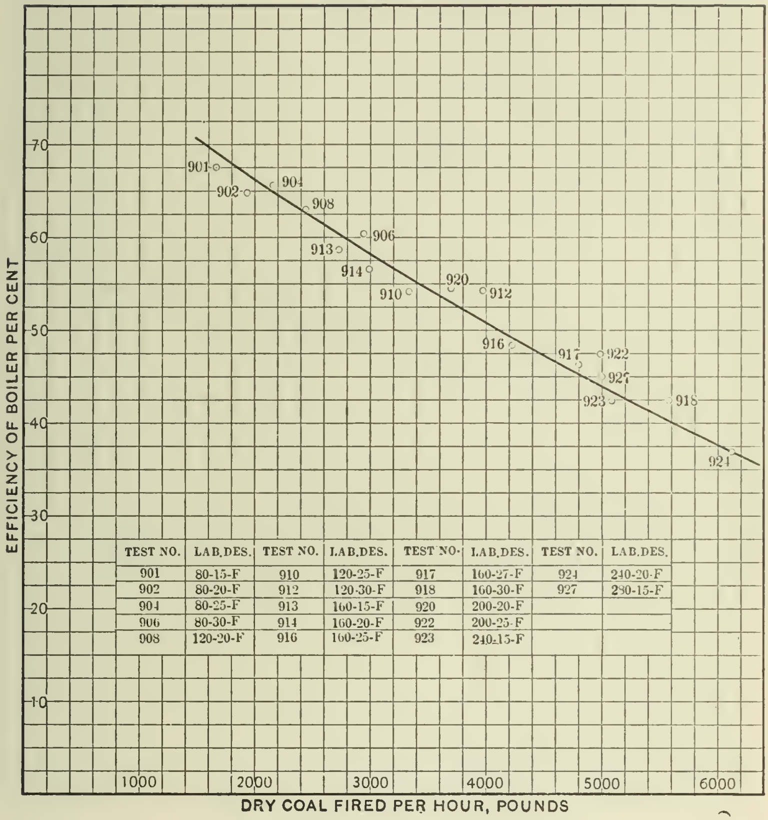
DRY STEAM PER SQ. FT. OF HEATING SURFACE PER HOUR

PLOT No. 902.



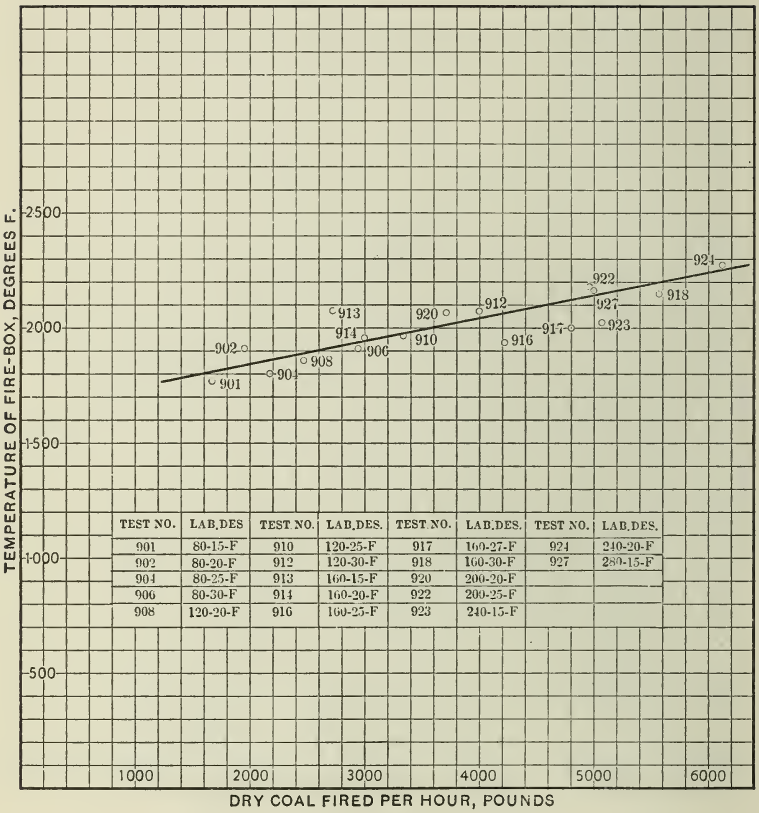
TEST NO.	LAB. DES.	TEST NO.	LAB. DES.	TEST NO.	LAB. DES.	TEST NO.	LAB. DES.
901	80-15-F	910	120-25-F	917	160-27-F	924	240-20-F
902	80-20-F	912	120-30-F	918	160-30-F	927	280-15-F
904	80-25-F	913	160-15-F	920	200-20-F		
906	80-30-F	914	160-20-F	922	200-25-F		
908	120-20-F	916	160-25-F	923	240-15-F		

PLOT No. 903.



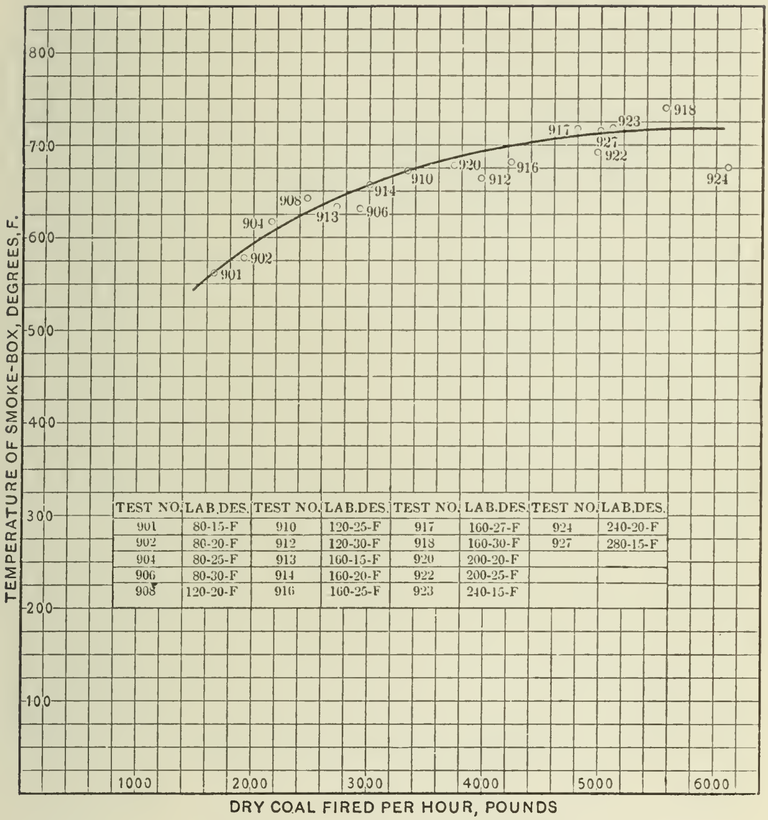
TEST NO.	LAB.DES.	TEST NO.	LAB.DES.	TEST NO.	LAB.DES.	TEST NO.	LAB.DES.
901	80-15-F	910	120-25-F	917	160-27-F	924	240-20-F
902	80-20-F	912	120-30-F	918	160-30-F	927	280-15-F
904	80-25-F	913	160-15-F	920	200-20-F		
906	80-30-F	914	160-20-F	922	200-25-F		
908	120-20-F	916	160-25-F	923	240-15-F		

PLOT No. 904.



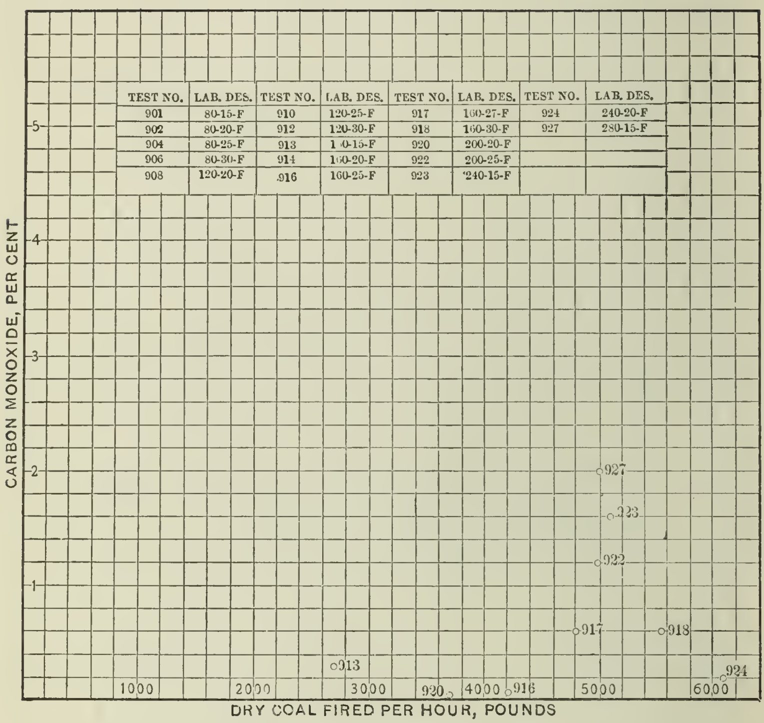
TEST NO.	LAB.DES	TEST NO.	LAB.DES.	TEST NO.	LAB.DES.	TEST NO.	LAB.DES.
901	80-15-F	910	120-25-F	917	160-27-F	924	240-20-F
902	80-20-F	912	120-30-F	918	160-30-F	927	280-15-F
904	80-25-F	913	160-15-F	920	200-20-F		
906	80-30-F	914	160-20-F	922	200-25-F		
908	120-20-F	916	160-25-F	923	240-15-F		

PLOT No. 905.



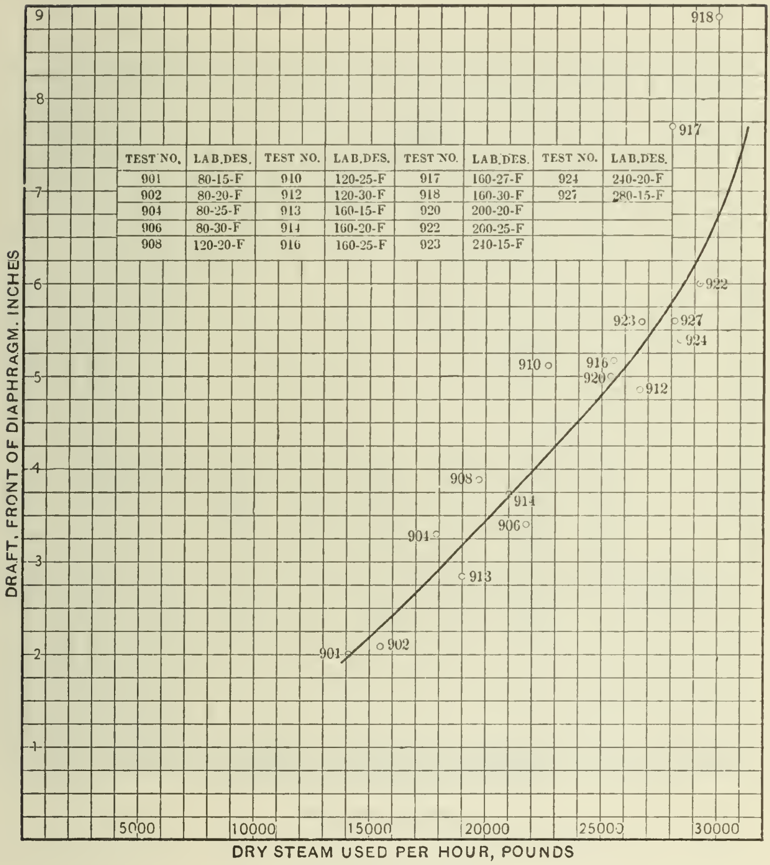
TEST NO.	LAB.DES.	TEST NO.	LAB.DES.	TEST NO.	LAB.DES.	TEST NO.	LAB.DES.
901	80-15-F	910	120-25-F	917	160-27-F	924	240-20-F
902	80-20-F	912	120-30-F	918	160-30-F	927	280-15-F
904	80-25-F	913	160-15-F	920	200-20-F		
906	80-30-F	914	160-20-F	922	200-25-F		
908	120-20-F	916	160-25-F	923	240-15-F		

PLOT No. 906.



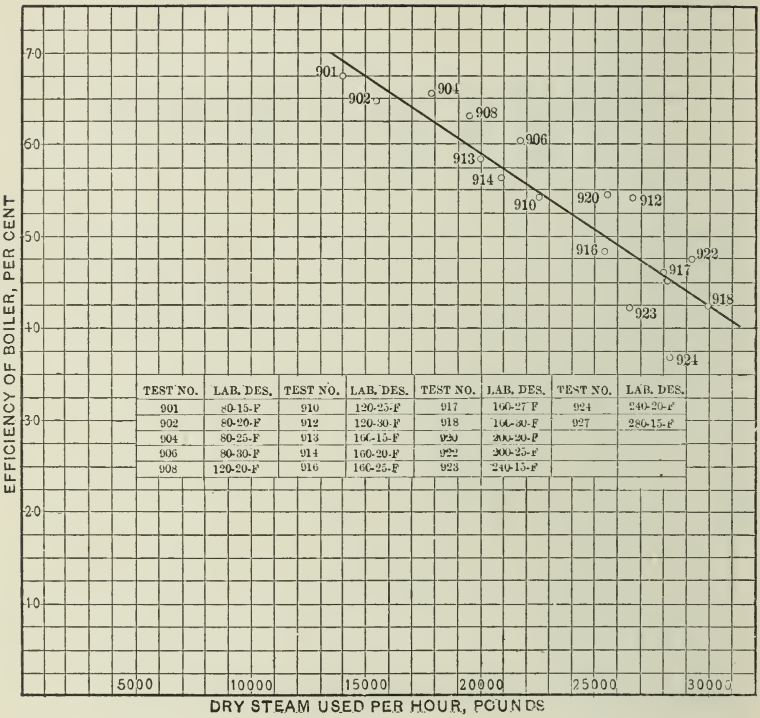
TEST NO.	LAB. DES.	TEST NO.	LAB. DES.	TEST NO.	LAB. DES.	TEST NO.	LAB. DES.
901	80-15-F	910	120-25-F	917	160-27-F	924	240-20-F
902	80-20-F	912	120-30-F	918	160-30-F	927	280-15-F
904	80-25-F	913	1[illegible]0-15-F	920	200-20-F		
906	80-30-F	914	160-20-F	922	200-25-F		
908	120-20-F	916	160-25-F	923	240-15-F		

PLOT No. 907.



TEST NO.	LAB.DES.	TEST NO.	LAB.DES.	TEST NO.	LAB.DES.	TEST NO.	LAB.DES.
901	80-15-F	910	120-25-F	917	160-27-F	924	240-20-F
902	80-20-F	912	120-30-F	918	160-30-F	927	280-15-F
904	80-25-F	913	160-15-F	920	200-20-F		
906	80-30-F	914	160-20-F	922	200-25-F		
908	120-20-F	916	160-25-F	923	240-15-F		

PLOT No. 908.



TEST NO.	LAB. DES.	TEST NO.	LAB. DES.	TEST NO.	LAB. DES.	TEST NO.	LAB. DES.
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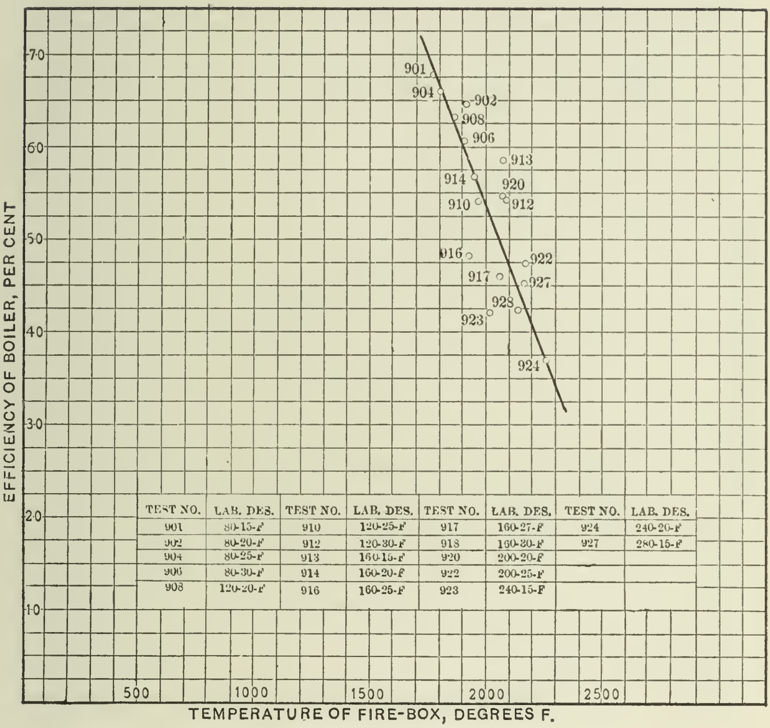
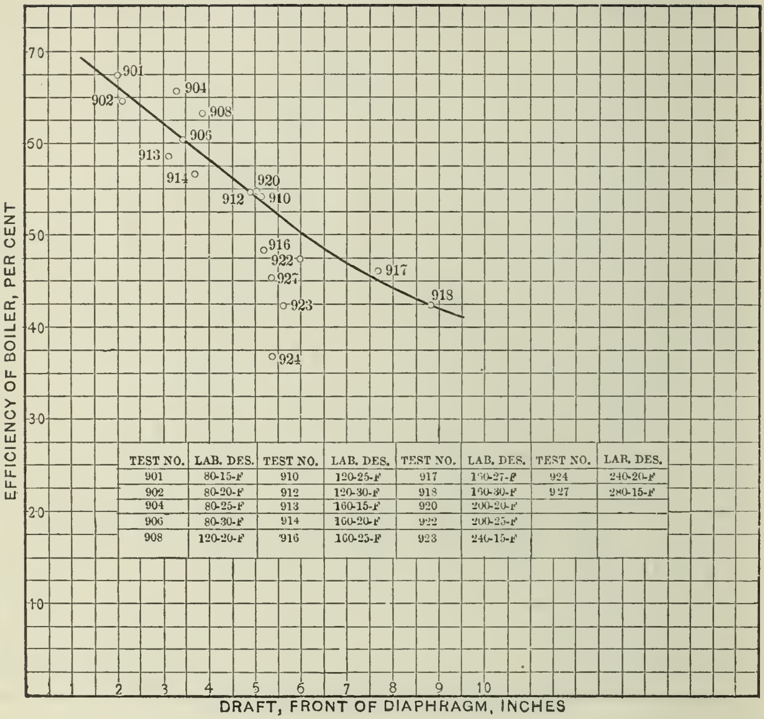
902	80-20-F	912	120-30-F	918	160-30-F	927	280-15-F
904	80-25-F	913	160-15-F	920	200-20-F		
906	80-30-F	914	160-20-F	922	200-25-F		
908	120-20-F	916	160-25-F	923	240-15-F		

PLOT No. 909.



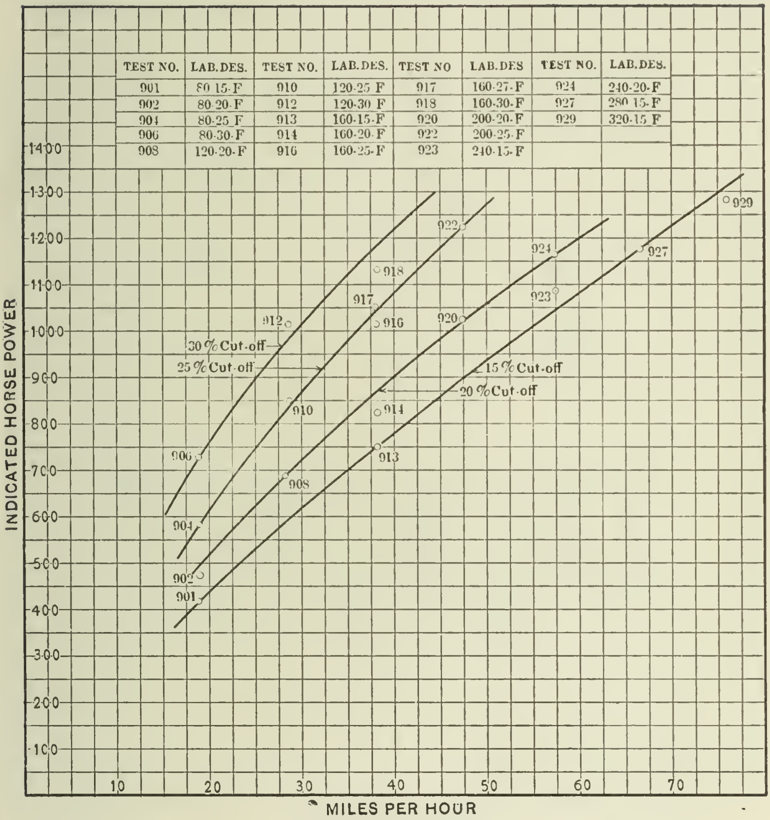
TEST NO.	LAB. DES.	TEST NO.	LAB. DES.	TEST NO.	LAB. DES.	TEST NO.	LAB. DES.
901	80-15-F	910	120-25-F	917	160-27-F	924	240-20-F
902	80-20-F	912	120-30-F	918	160-30-F	927	280-15-F
904	80-25-F	913	160-15-F	920	200-20-F		
906	80-30-F	914	160-20-F	922	200-25-F		
908	120-20-F	916	160-25-F	923	240-15-F		

PLOT No. 910.

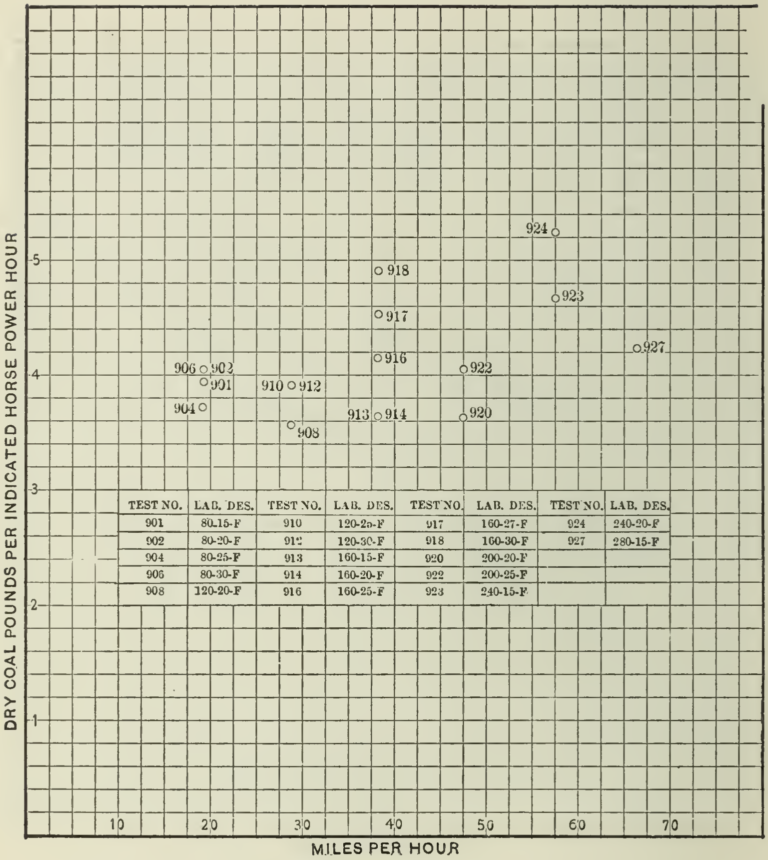


TEST NO.	LAB. DES.	TEST NO.	LAB. DES.	TEST NO.	LAB. DES.	TEST NO.	LAB. DES.
901	80-15-F	910	120-25-F	917	160-27-F	924	240-20-F
902	80-20-F	912	120-30-F	918	160-30-F	927	280-15-F
904	80-25-F	913	160-15-F	920	200-20-F		
906	80-30-F	914	160-20-F	922	200-25-F		
908	120-20-F	916	160-25-F	923	240-15-F		

PLOT No. 911.

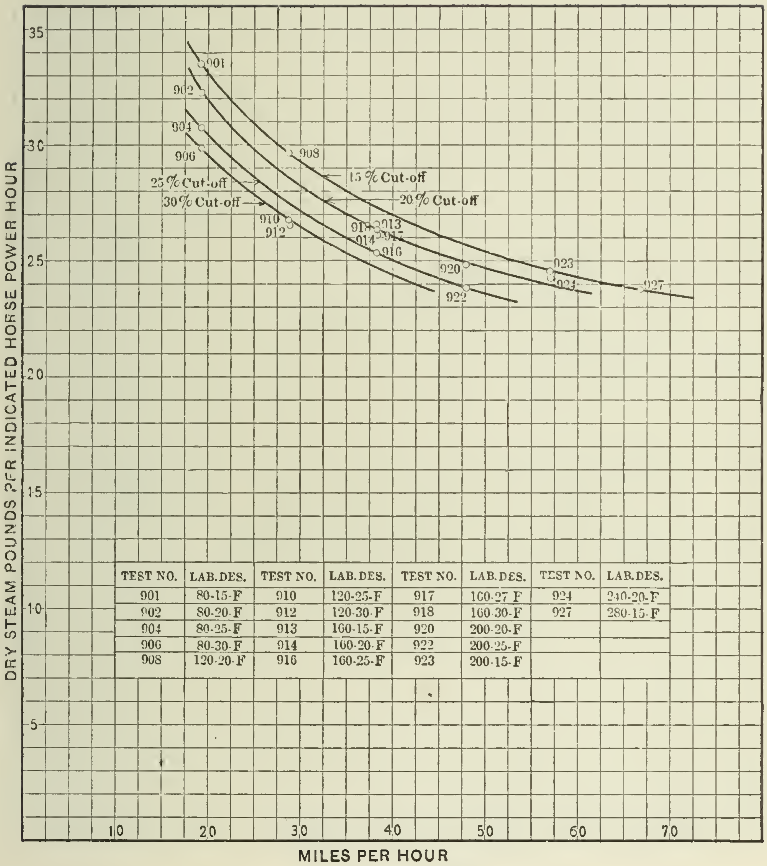

TEST NO. LAB.DES. TEST NO. LAB.DES. TEST NO LAB.DES TEST NO. LAB.DES.
901 80·15·F 910 120·25·F 917 160·27·F 924 240·20·F
902 80·20·F 912 120·30·F 918 160·30·F 927 280·15·F
904 80·25·F 913 160·15·F 920 200·20·F 929 320·15·F
906 80·30·F 914 160·20·F 922 200·25·F
908 120·20·F 916 160·25·F 923 240·15·F
30 % Cut-off
25 % Cut-off
15 % Cut-off
20 % Cut-off
INDICATED HORSE POWER
MILES PER HOUR

PLOT No. 920.



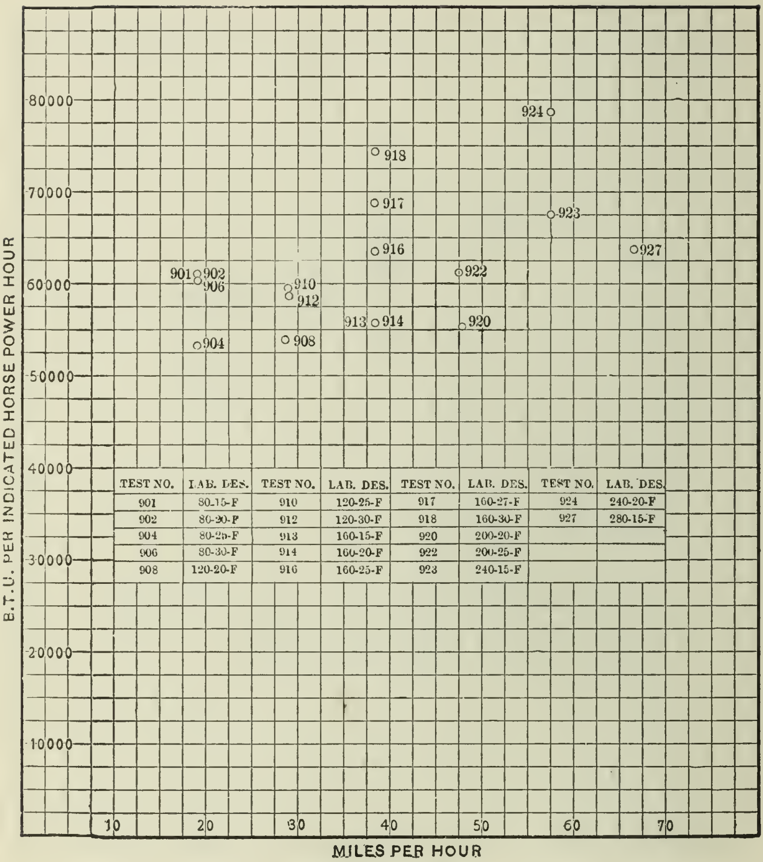
TEST NO.	LAB. DES.	TEST NO.	LAB. DES.	TEST NO.	LAB. DES.	TEST NO.	LAB. DES.
901	80-15-F	910	120-25-F	917	160-27-F	924	240-20-F
902	80-20-F	912	120-30-F	918	160-30-F	927	280-15-F
904	80-25-F	913	160-15-F	920	200-20-F		
906	80-30-F	914	160-20-F	922	200-25-F		
908	120-20-F	916	160-25-F	923	240-15-F		

PLOT No. 921.



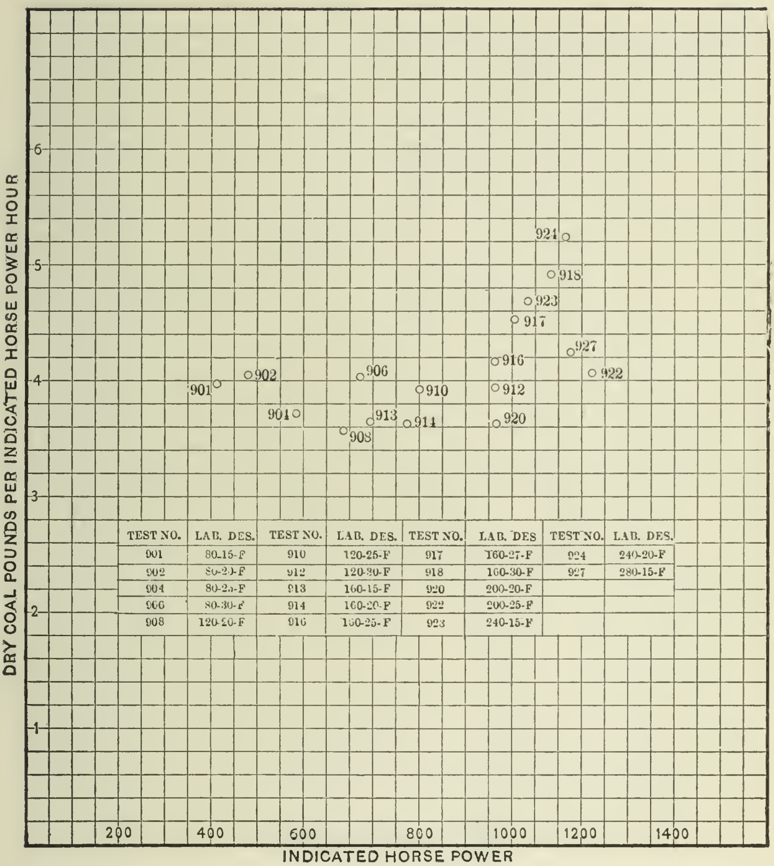
TEST NO.	LAB.DES.	TEST NO.	LAB.DES.	TEST NO.	LAB.DES.	TEST NO.	LAB.DES.
901	80-15-F	910	120-25-F	917	160-27 F	924	240-20-F
902	80-20-F	912	120-30-F	918	160-30-F	927	280-15-F
904	80-25-F	913	160-15-F	920	200-20-F		
906	80-30-F	914	160-20-F	922	200-25-F		
908	120-20-F	916	160-25-F	923	200-15-F		

PLOT No. 922.



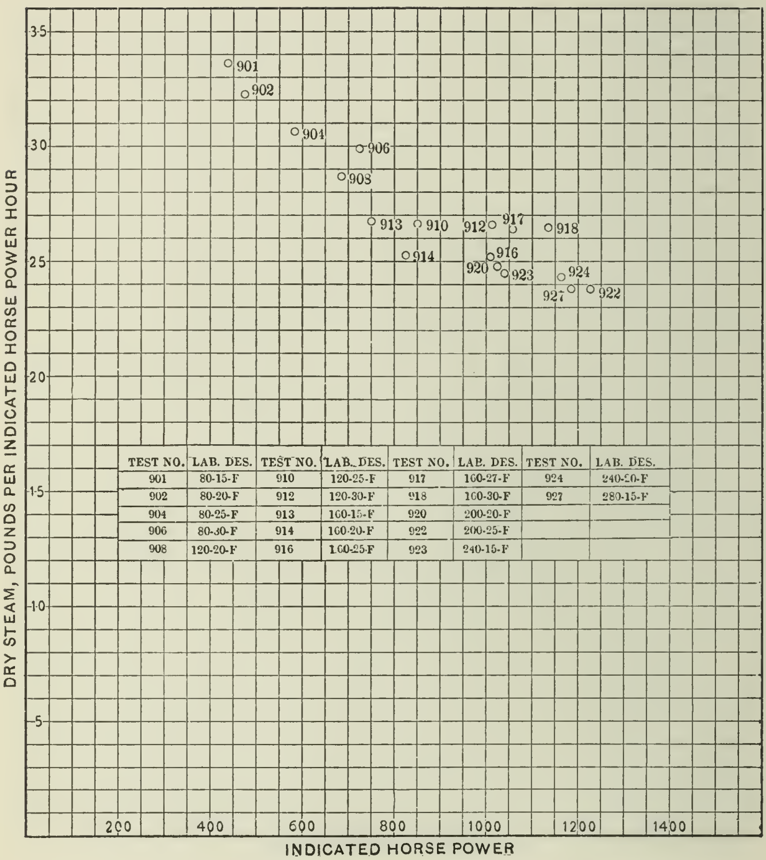
TEST NO.	LAB. DES.	TEST NO.	LAB. DES.	TEST NO.	LAB. DES.	TEST NO.	LAB. DES.
901	80-15-F	910	120-25-F	917	160-27-F	924	240-20-F
902	80-20-F	912	120-30-F	918	160-30-F	927	280-15-F
904	80-25-F	913	160-15-F	920	200-20-F		
906	80-30-F	914	160-20-F	922	200-25-F		
908	120-20-F	916	160-25-F	923	240-15-F		

PLOT No. 923.



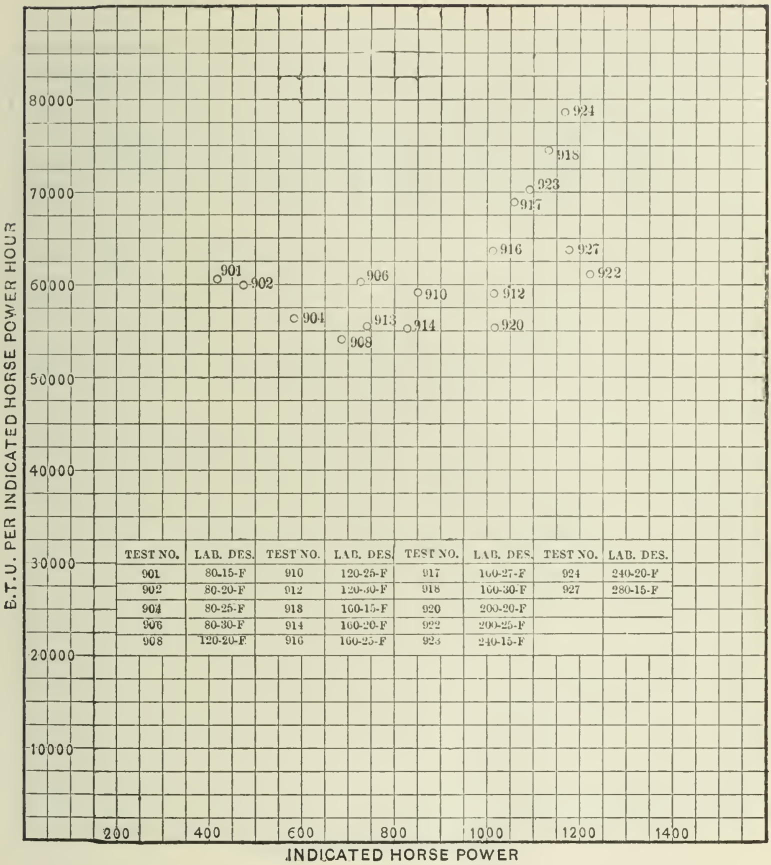
TEST NO.	LAB. DES.	TEST NO.	LAB. DES.	TEST NO.	LAB. DES	TEST NO.	LAB. DES.
901	80-15-F	910	120-25-F	917	160-27-F	924	240-20-F
902	80-20-F	912	120-30-F	918	160-30-F	927	280-15-F
904	80-25-F	913	160-15-F	920	200-20-F		
906	80-30-F	914	160-20-F	922	200-25-F		
908	120-20-F	916	160-25-F	923	240-15-F		

PLOT No. 924.



TEST NO.	LAB. DES.	TEST NO.	LAB. DES.	TEST NO.	LAB. DES.	TEST NO.	LAB. DES.
901	80-15-F	910	120-25-F	917	160-27-F	924	240-20-F
902	80-20-F	912	120-30-F	918	160-30-F	927	280-15-F
904	80-25-F	913	160-15-F	920	200-20-F		
906	80-30-F	914	160-20-F	922	200-25-F		
908	120-20-F	916	160-25-F	923	240-15-F		

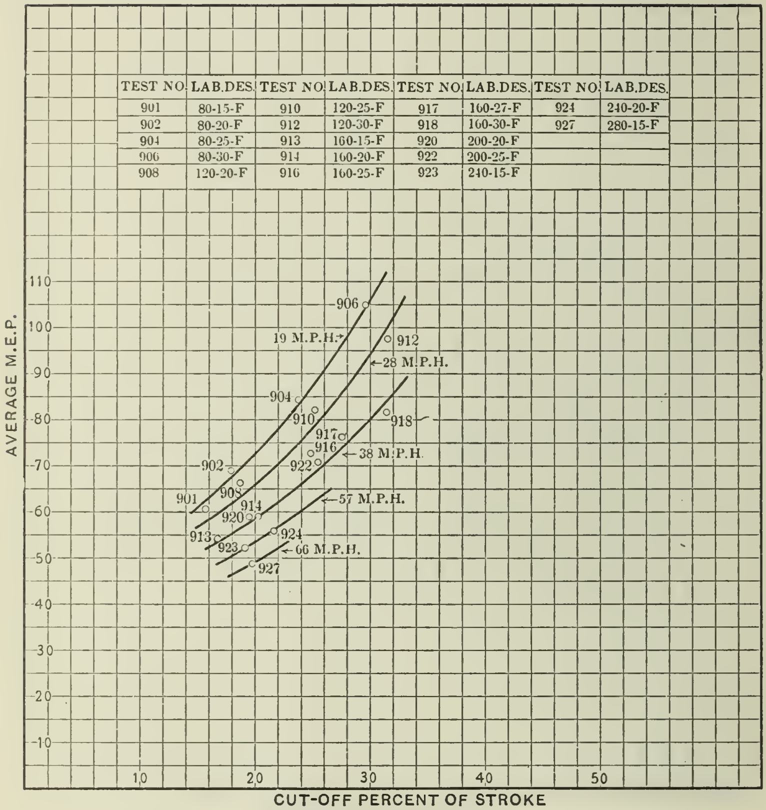
PLOT No. 925.



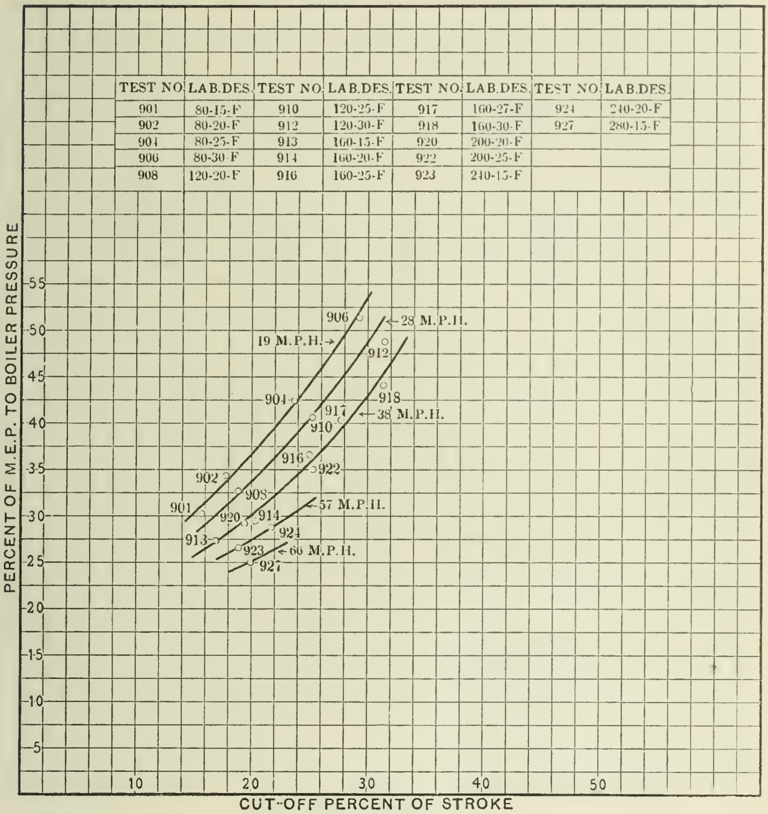
TEST NO.	LAB. DES.	TEST NO.	LAB. DES.	TEST NO.	LAB. DES.	TEST NO.	LAB. DES.
901	80-15-F	910	120-25-F	917	160-27-F	924	240-20-F
902	80-20-F	912	120-30-F	918	160-30-F	927	280-15-F
904	80-25-F	918	160-15-F	920	200-20-F		
906	80-30-F	914	160-20-F	922	200-25-F		
908	120-20-F	916	160-25-F	923	240-15-F		

PLOT No. 926.

TEST NO.	LAB.DES.	TEST NO.	LAB.DES.	TEST NO.	LAB.DES.	TEST NO.	LAB.DES.
901	80-15-F	910	120-25-F	917	160-27-F	924	240-20-F
902	80-20-F	912	120-30-F	918	160-30-F	927	280-15-F
904	80-25-F	913	160-15-F	920	200-20-F		
906	80-30-F	914	160-20-F	922	200-25-F		
908	120-20-F	916	160-25-F	923	240-15-F		



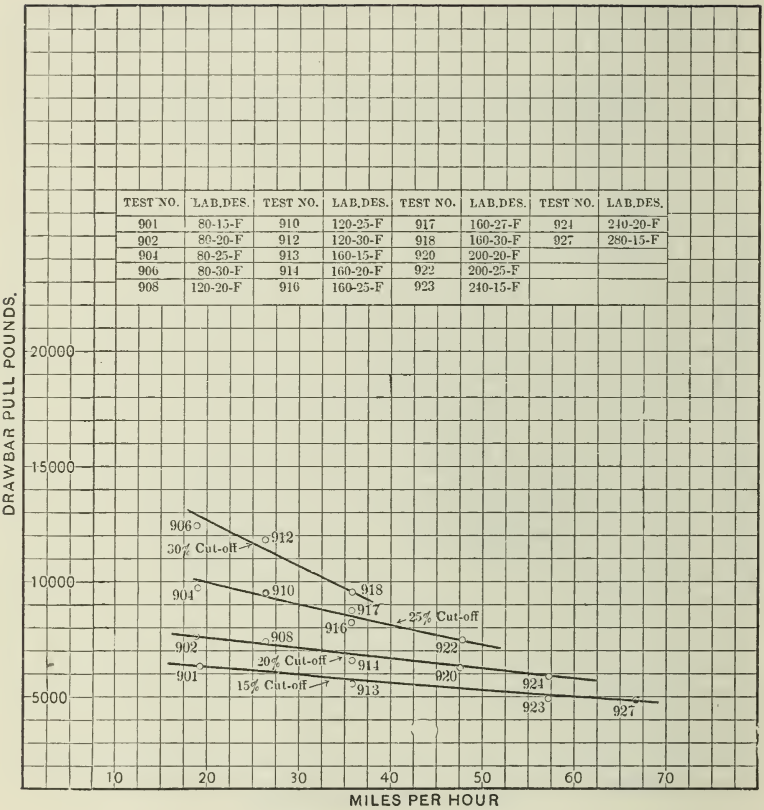
PLOT No. 927.



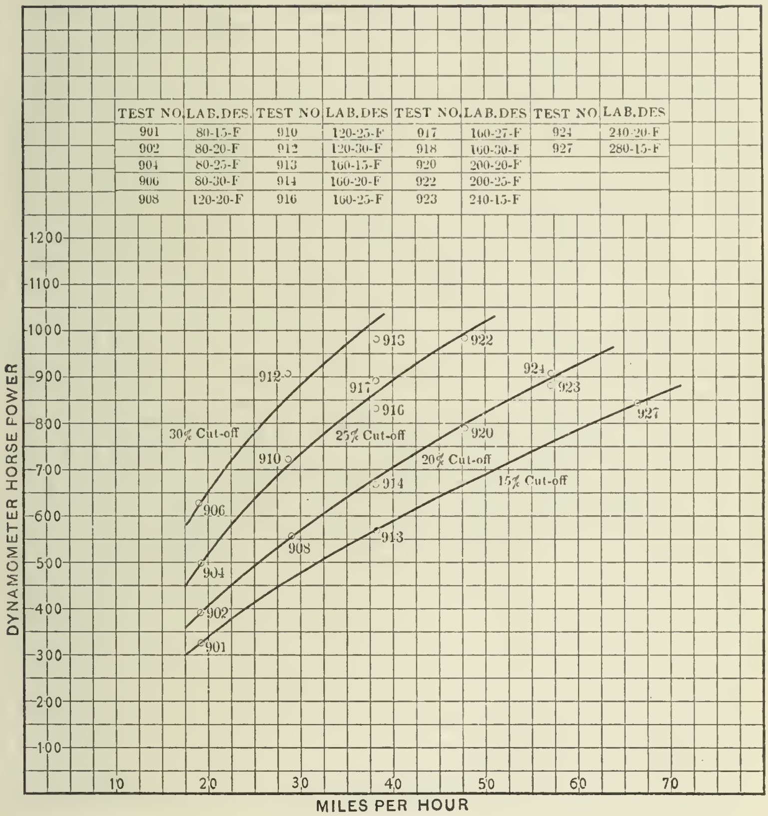
TEST NO.	LAB.DES.	TEST NO.	LAB.DES.	TEST NO.	LAB.DES.	TEST NO.	LAB.DES.
901	80-15-F	910	120-25-F	917	160-27-F	924	240-20-F
902	80-20-F	912	120-30-F	918	160-30-F	927	280-15-F
904	80-25-F	913	160-15-F	920	200-20-F		
906	80-30-F	914	160-20-F	922	200-25-F		
908	120-20-F	916	160-25-F	923	240-15-F		

PLOT No. 928.

TEST NO.	LAB.DES.	TEST NO.	LAB.DES.	TEST NO.	LAB.DES.	TEST NO.	LAB.DES.
901	80-15-F	910	120-25-F	917	160-27-F	924	240-20-F
902	80-20-F	912	120-30-F	918	160-30-F	927	280-15-F
904	80-25-F	913	160-15-F	920	200-20-F		
906	80-30-F	914	160-20-F	922	200-25-F		
908	120-20-F	916	160-25-F	923	240-15-F		

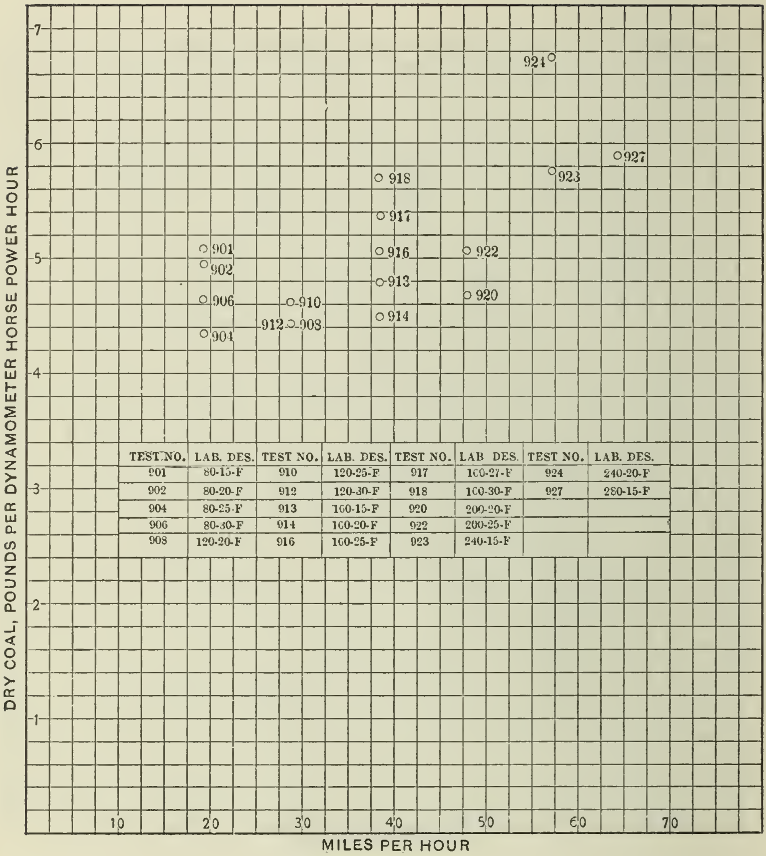


PLOT No. 940.



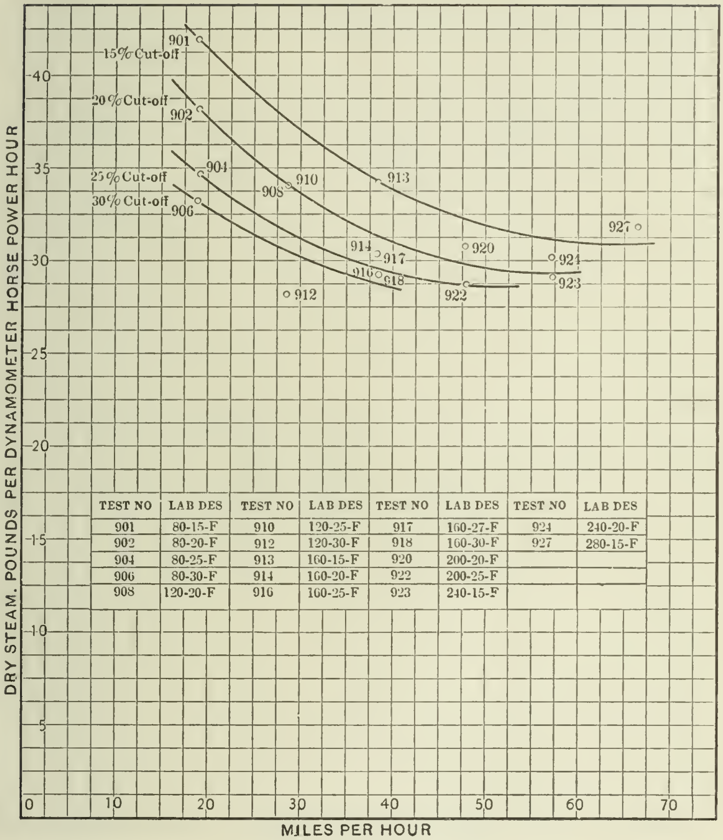
TEST NO.	LAB.DES.	TEST NO	LAB.DES	TEST NO.	LAB.DES	TEST NO	LAB.DES
901	80-15-F	910	120-25-F	917	160-27-F	924	240-20-F
902	80-20-F	912	120-30-F	918	160-30-F	927	280-15-F
904	80-25-F	913	160-15-F	920	200-20-F		
906	80-30-F	914	160-20-F	922	200-25-F		
908	120-20-F	916	160-25-F	923	240-15-F		

PLOT No. 941.



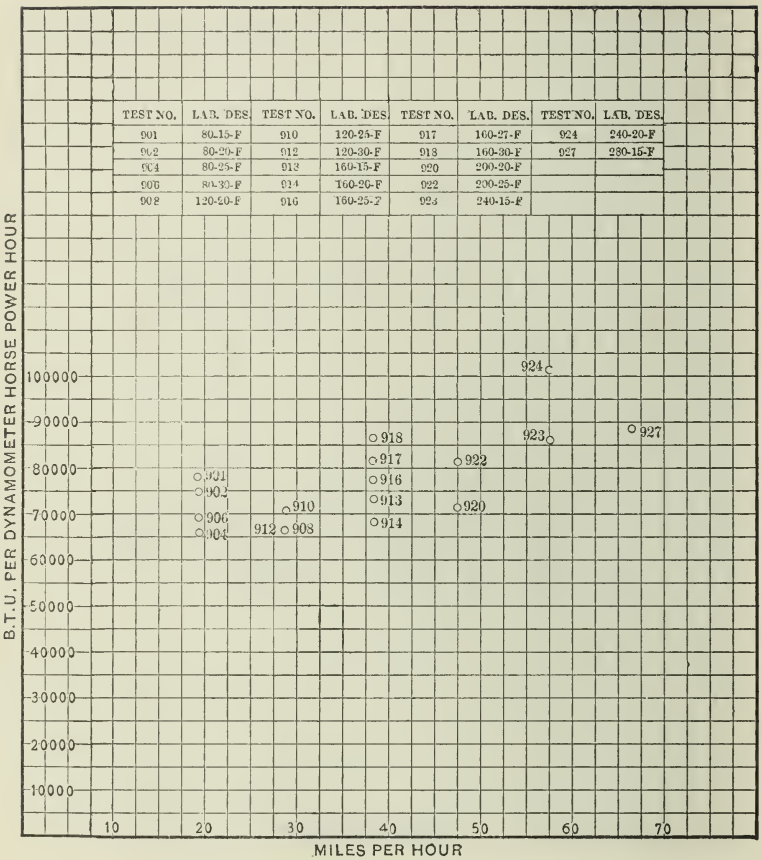
TEST NO.	LAB. DES.	TEST NO.	LAB. DES.	TEST NO.	LAB. DES.	TEST NO.	LAB. DES.
901	80-15-F	910	120-25-F	917	100-27-F	924	240-20-F
902	80-20-F	912	120-30-F	918	100-30-F	927	280-15-F
904	80-25-F	913	100-15-F	920	200-20-F		
906	80-30-F	914	100-20-F	922	200-25-F		
908	120-20-F	916	100-25-F	923	240-15-F		

PLOT No. 942.



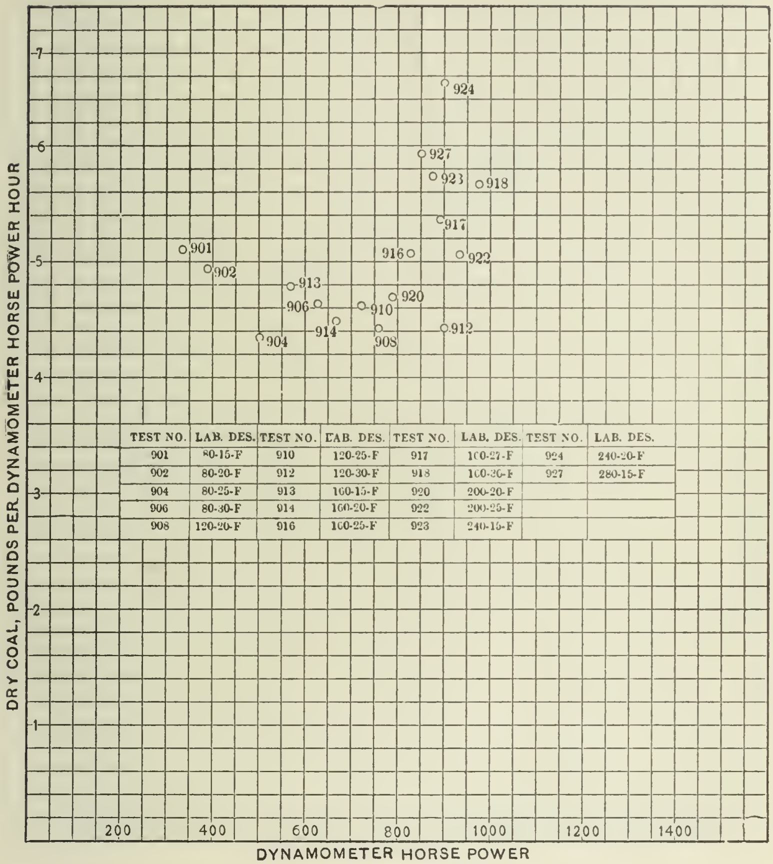
TEST NO	LAB DES	TEST NO	LAB DES	TEST NO	LAB DES	TEST NO	LAB DES
901	80-15-F	910	120-25-F	917	160-27-F	924	240-20-F
902	80-20-F	912	120-30-F	918	160-30-F	927	280-15-F
904	80-25-F	913	160-15-F	920	200-20-F		
906	80-30-F	914	160-20-F	922	200-25-F		
908	120-20-F	916	160-25-F	923	240-15-F		

PLOT No. 943.



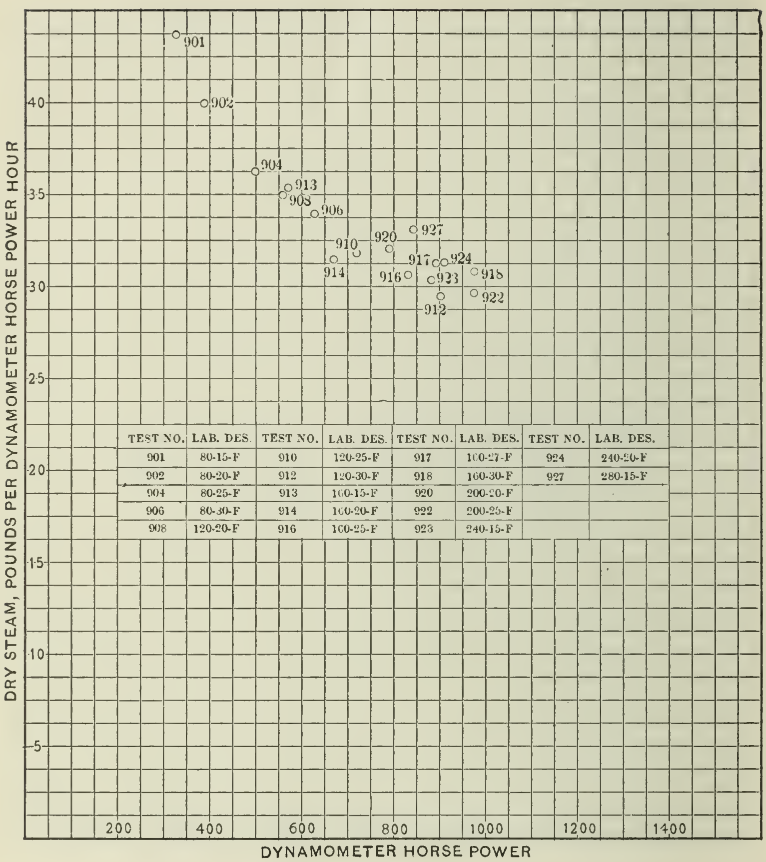
TEST NO.	LAB. DES.	TEST NO.	LAB. DES.	TEST NO.	LAB. DES.	TEST NO.	LAB. DES.
901	80-15-F	910	120-25-F	917	160-27-F	924	240-20-F
902	80-20-F	912	120-30-F	918	160-30-F	927	280-15-F
904	80-25-F	913	160-15-F	920	200-20-F		
906	80-30-F	914	160-20-F	922	200-25-F		
908	120-20-F	916	160-25-F	923	240-15-F		

PLOT No. 944.



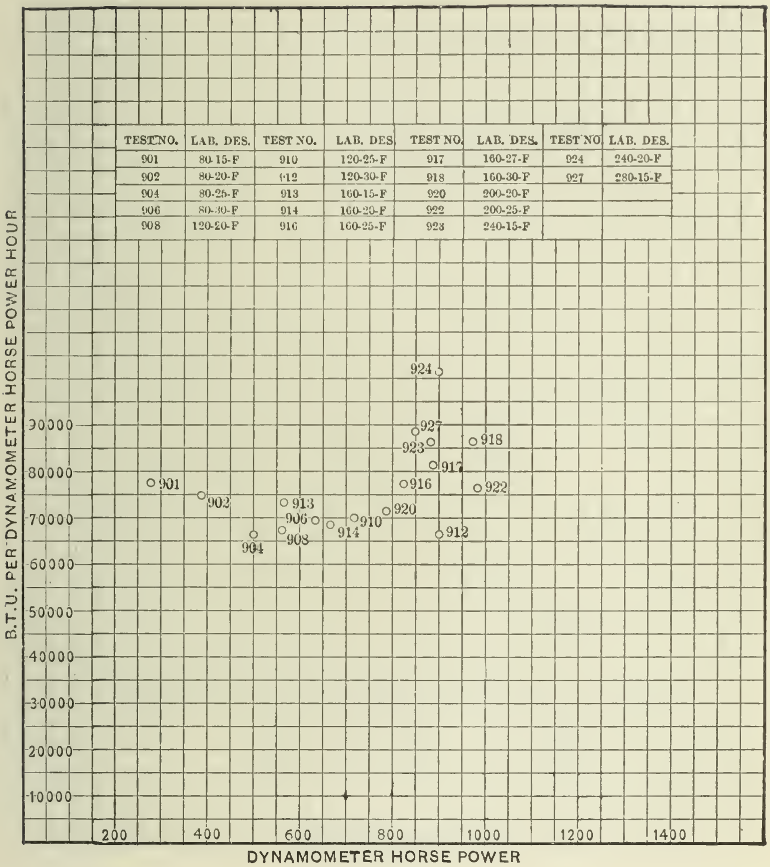
TEST NO.	LAB. DES.	TEST NO.	LAB. DES.	TEST NO.	LAB. DES.	TEST NO.	LAB. DES.
901	80-15-F	910	120-25-F	917	160-27-F	924	240-20-F
902	80-20-F	912	120-30-F	918	160-30-F	927	280-15-F
904	80-25-F	913	160-15-F	920	200-20-F		
906	80-30-F	914	160-20-F	922	200-25-F		
908	120-20-F	916	160-25-F	923	240-15-F		

PLOT No. 945.



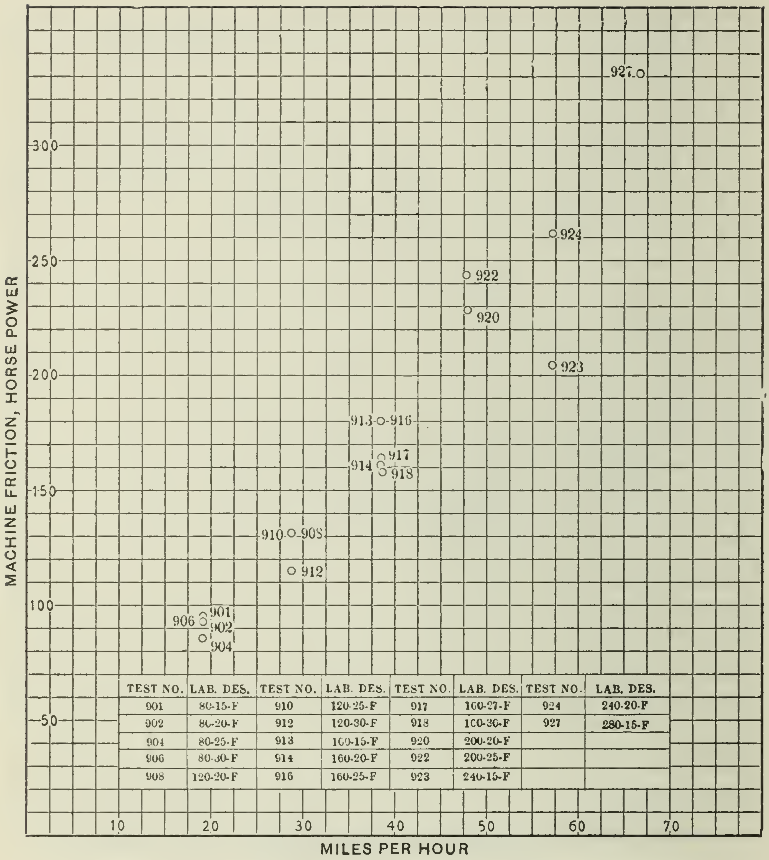
TEST NO.	LAB. DES.	TEST NO.	LAB. DES.	TEST NO.	LAB. DES.	TEST NO.	LAB. DES.
901	80-15-F	910	120-25-F	917	100-27-F	924	240-20-F
902	80-20-F	912	120-30-F	918	160-30-F	927	280-15-F
904	80-25-F	913	100-15-F	920	200-20-F		
906	80-30-F	914	100-20-F	922	200-25-F		
908	120-20-F	916	100-25-F	923	240-15-F		

PLOT No. 946.



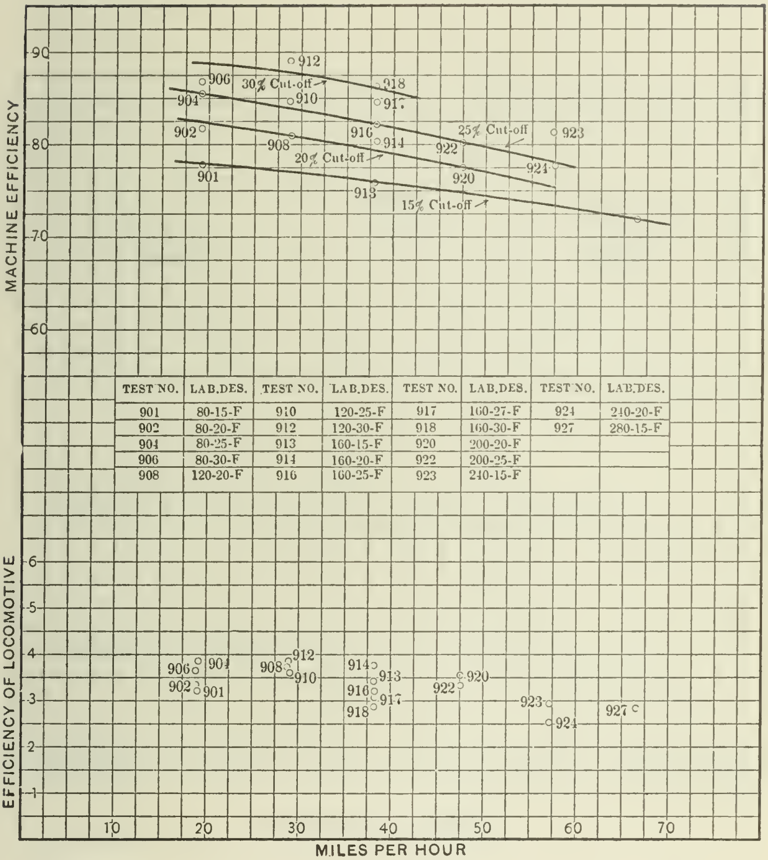
TEST NO.	LAB. DES.	TEST NO.	LAB. DES.	TEST NO.	LAB. DES.	TEST NO.	LAB. DES.
901	80-15-F	910	120-25-F	917	160-27-F	924	240-20-F
902	80-20-F	912	120-30-F	918	160-30-F	927	280-15-F
904	80-25-F	913	160-15-F	920	200-20-F		
906	80-30-F	914	160-20-F	922	200-25-F		
908	120-20-F	916	160-25-F	923	240-15-F		

PLOT No. 947.



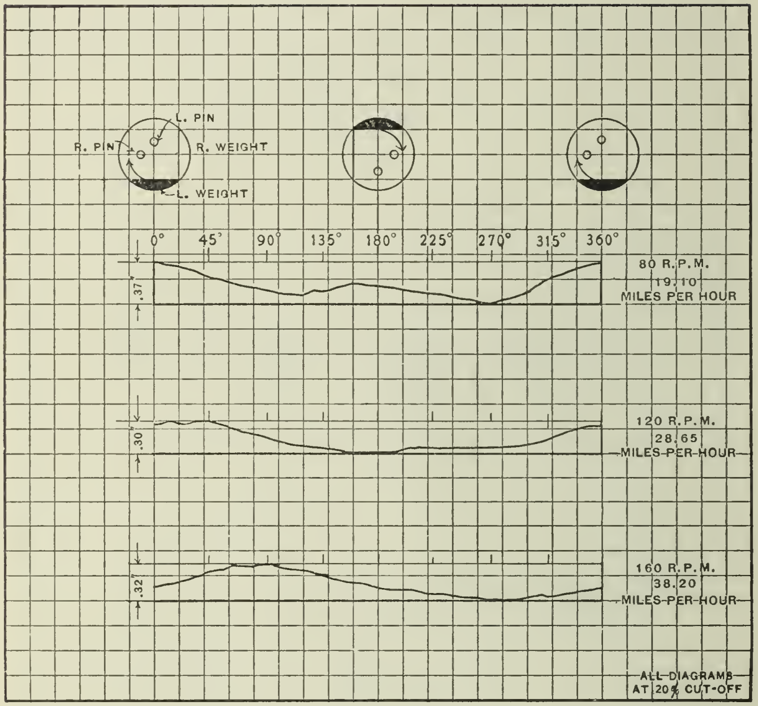
TEST NO.	LAB. DES.	TEST NO.	LAB. DES.	TEST NO.	LAB. DES.	TEST NO.	LAB. DES.
901	80-15-F	910	120-25-F	917	160-27-F	924	240-20-F
902	80-20-F	912	120-30-F	918	160-30-F	927	280-15-F
904	80-25-F	913	160-15-F	920	200-20-F		
906	80-30-F	914	160-20-F	922	200-25-F		
908	120-20-F	916	160-25-F	923	240-15-F		

PLOT No. 948.

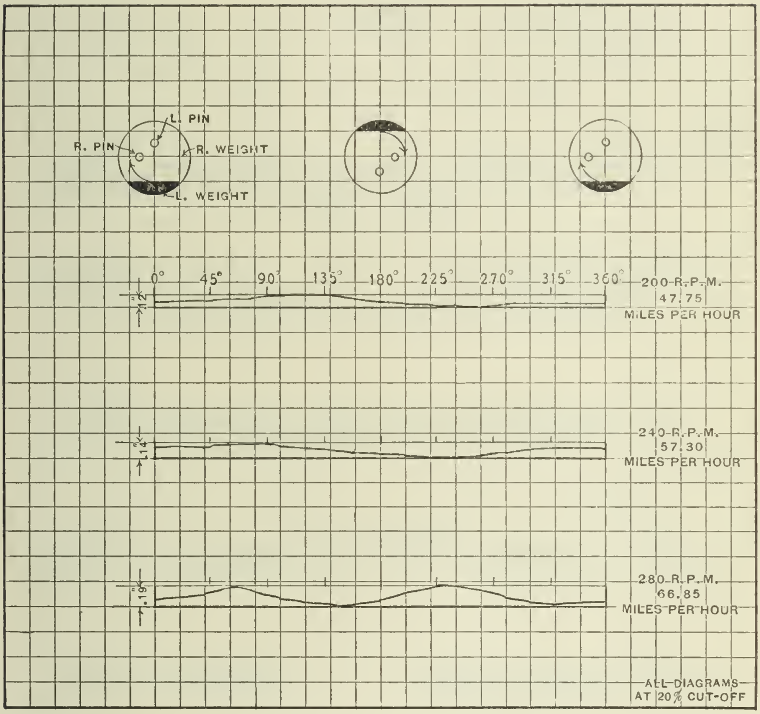


TEST NO.	LAB.DES.	TEST NO.	LAB.DES.	TEST NO.	LAB.DES.	TEST NO.	LAB.DES.
901	80-15-F	910	120-25-F	917	160-27-F	924	240-20-F
902	80-20-F	912	120-30-F	918	160-30-F	927	280-15-F
904	80-25-F	913	160-15-F	920	200-20-F		
906	80-30-F	914	160-20-F	922	200-25-F		
908	120-20-F	916	160-25-F	923	240-15-F		

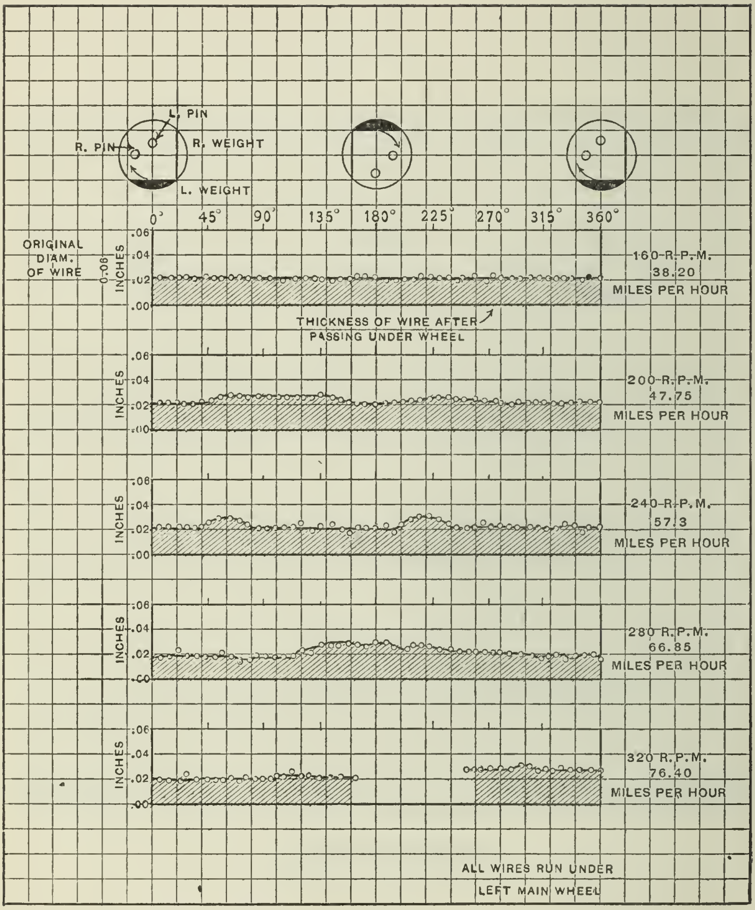
PLOT No. 949.



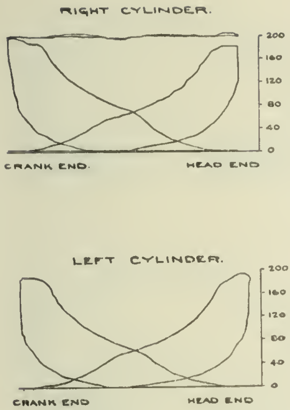
NOSING DIAGRAMS.



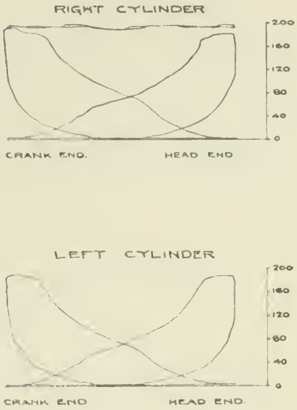
NOSING DIAGRAMS.



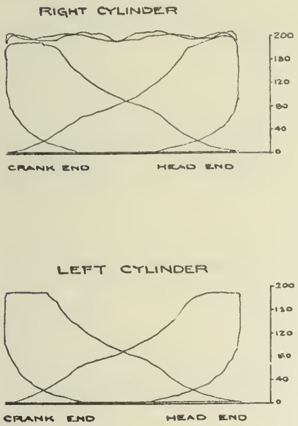
WIRE DIAGRAMS, COUNTERBALANCE TESTS.



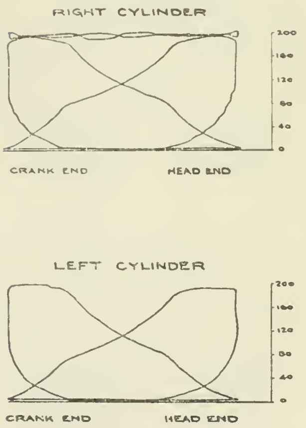
TEST No. 901 80-15-F
19.1 MILES PER HOUR.



TEST No. 902 80-20-F
19.1 MILES PER HOUR

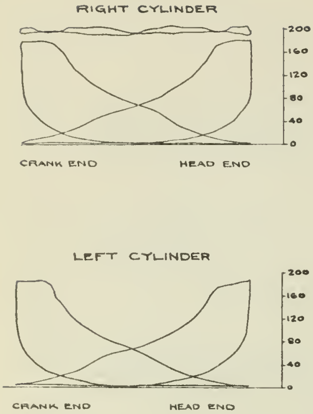


TEST No. 904 80-25-F
19.1 MILES PER HOUR

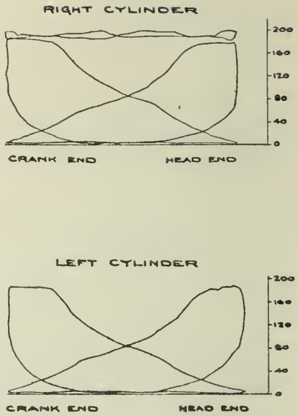


TEST No. 906 80-30-F
19.1 MILES PER HOUR

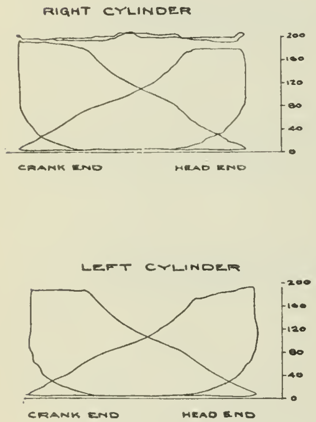
TYPICAL INDICATOR DIAGRAMS.



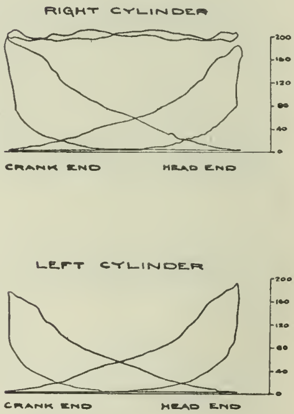
TEST No.908 120-20-F
28.65 MILES PER HOUR



TEST No. 910 120-25-F
28.65 MILES PER HOUR

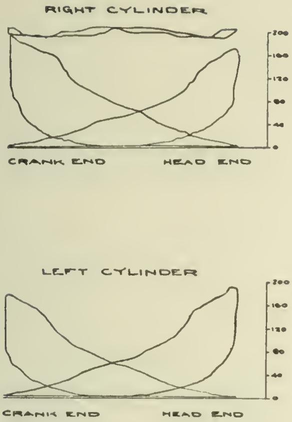


TEST No. 912 120-30-F
28.65 MILES PER HOUR

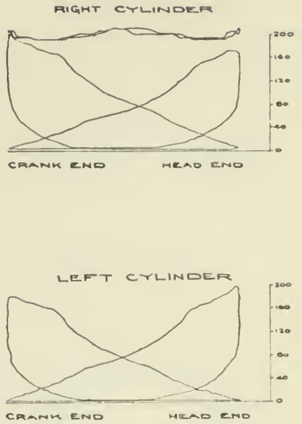


TEST No. 913 160-15-F
38.2 MILES PER HOUR

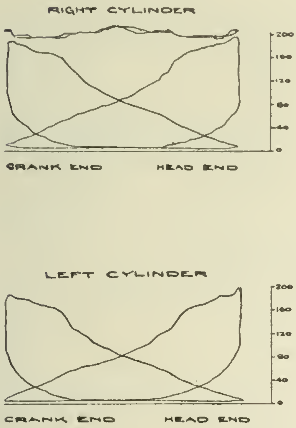
TYPICAL INDICATOR DIAGRAMS.



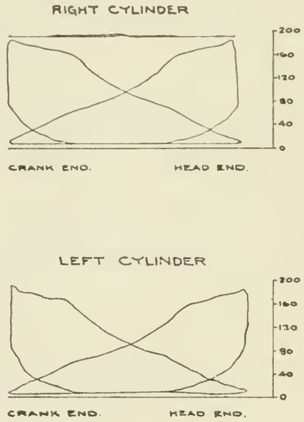
TEST No. 914 160-20-F
38.2 MILES PER HOUR



TEST No. 916 160-25-F
38.2 MILES PER HOUR

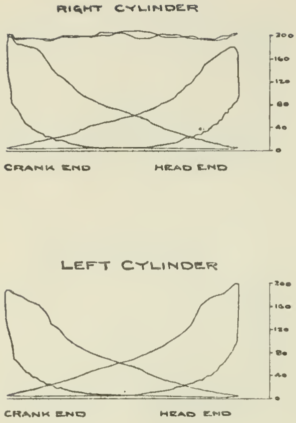


TEST No. 917 160-27-F.
38.2 MILES PER HOUR.

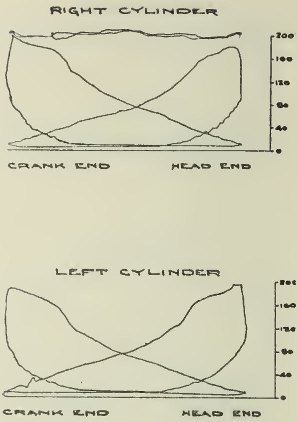


TEST No. 918 160-30-F
38.2 MILES PER HOUR.

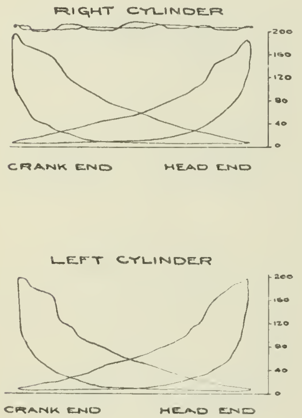
TYPICAL INDICATOR DIAGRAMS.



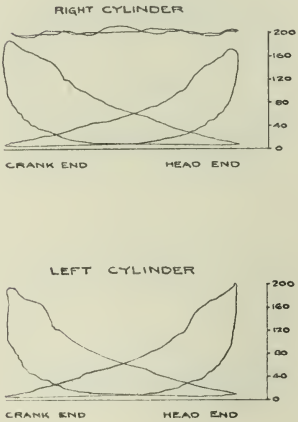
TEST No. 920. 200-20-F.
47.75 MILES PER HOUR



TEST No. 922 200-25-F
47.75 MILES PER HOUR

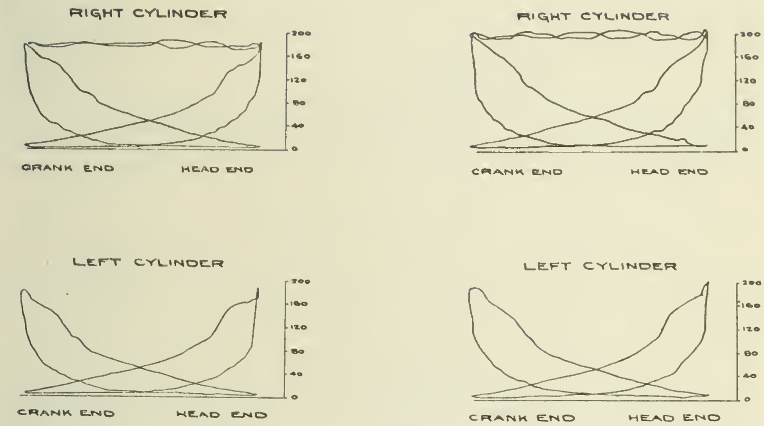


TEST No. 923 240-15-F
57.3 MILES PER HOUR



TEST No. 924 240-20-F.
57.3 MILES PER HOUR.

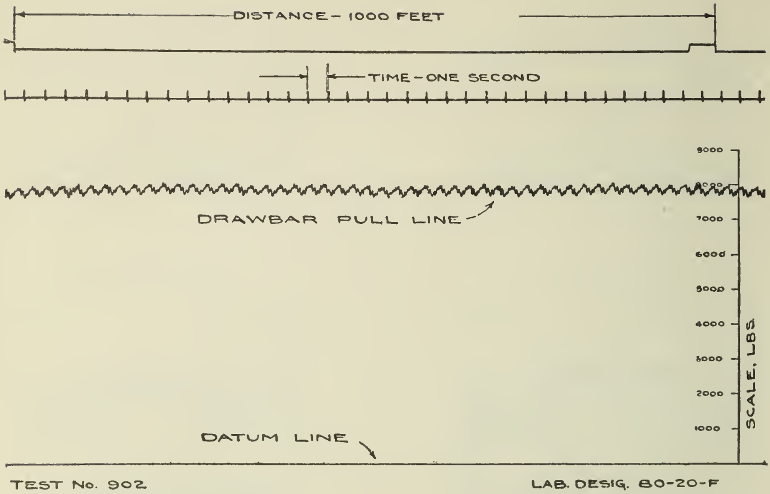
TYPICAL INDICATOR DIAGRAMS.

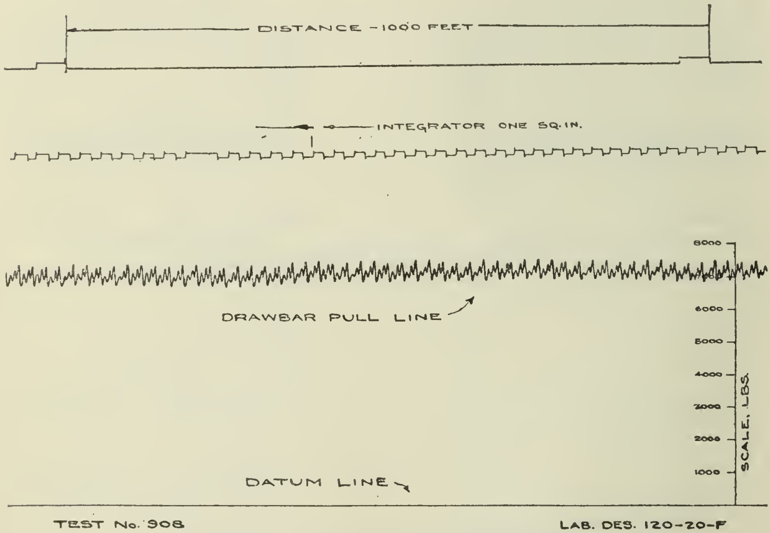


TEST No. 927 280-15-F
66.85 MILES PER HOUR

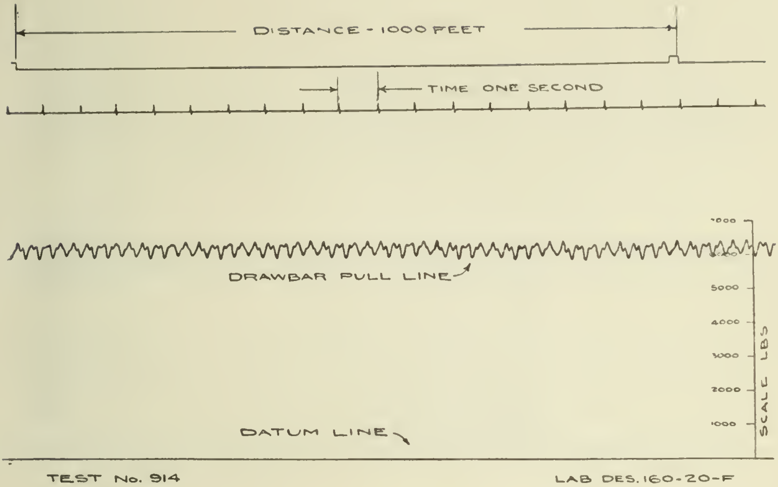
TEST No. 929 320-15-F
76.04 MILES PER HOUR

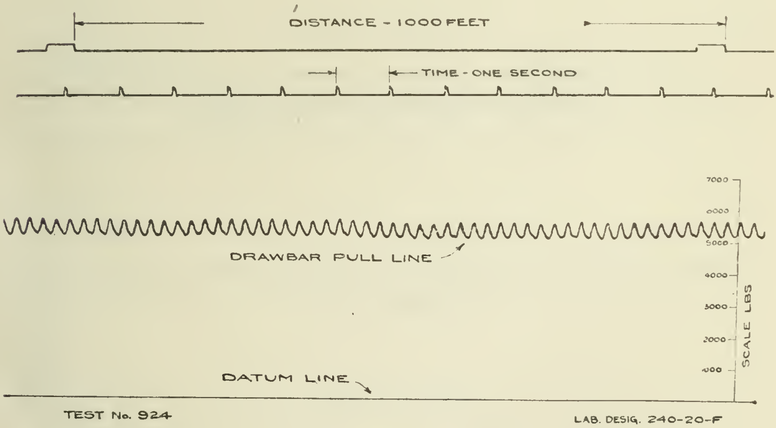
TYPICAL INDICATOR DIAGRAMS.



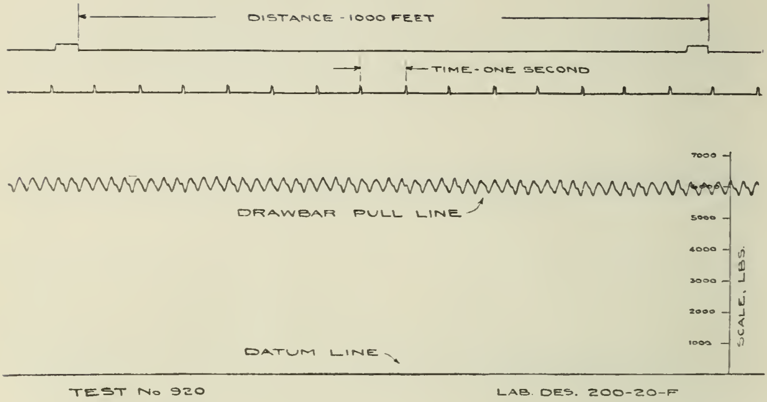


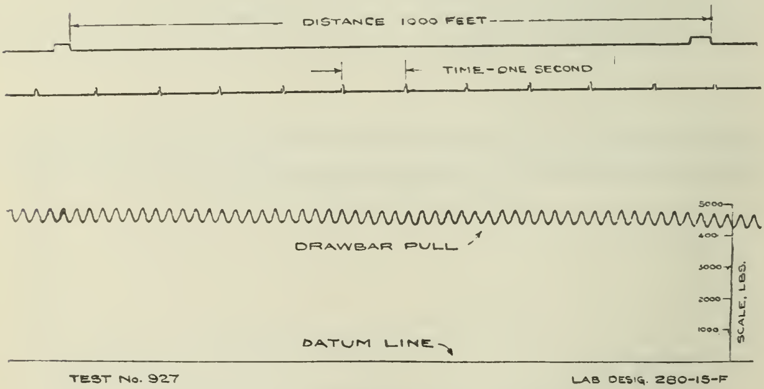
TYPICAL DYNAMOMETER DIAGRAMS.



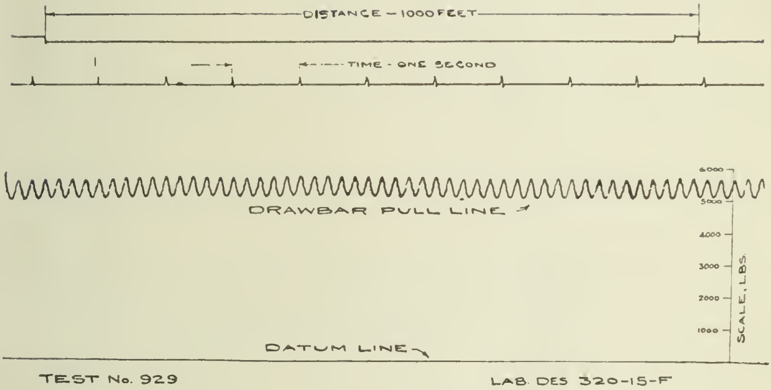


TYPICAL DYNAMOMETER DIAGRAMS.





TYPICAL DYNAMOMETER DIAGRAMS.



TYPICAL DYNAMOMETER DIAGRAMS.

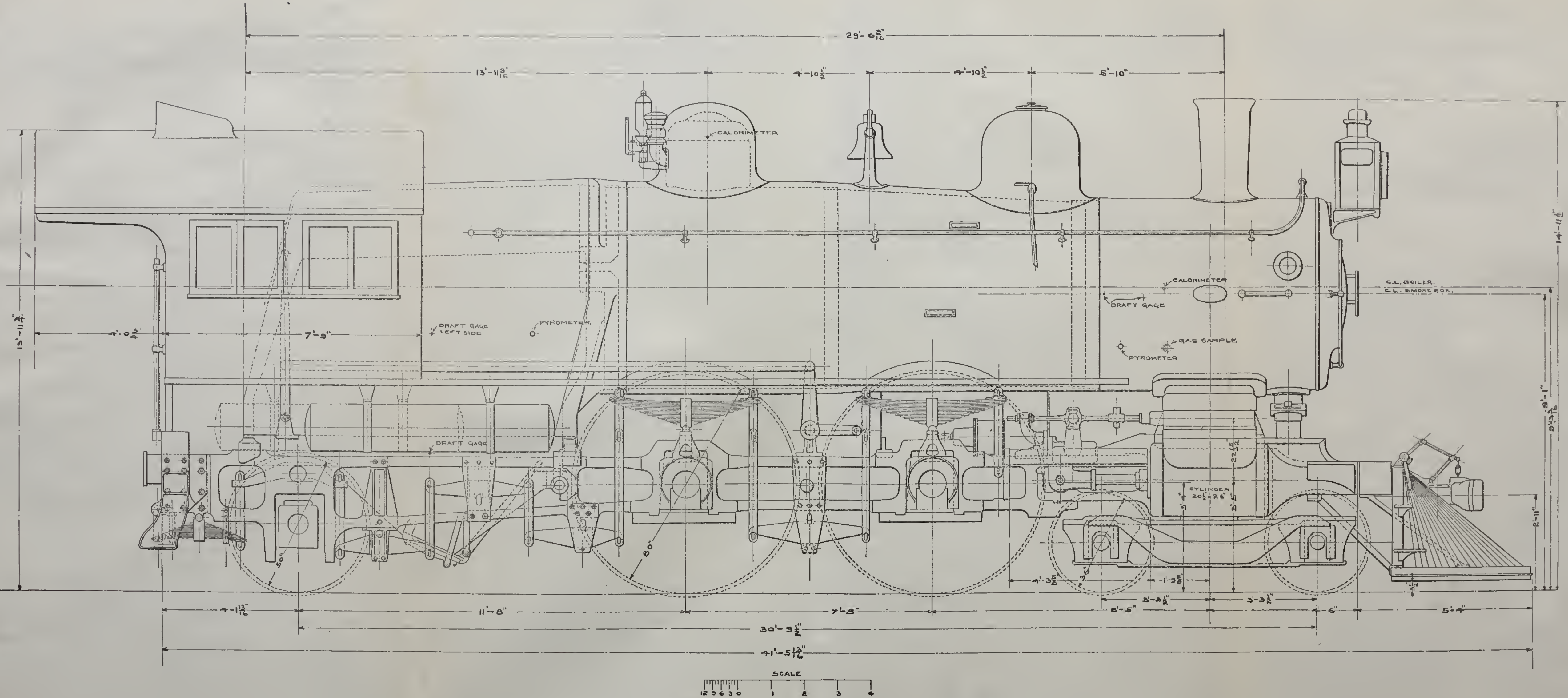
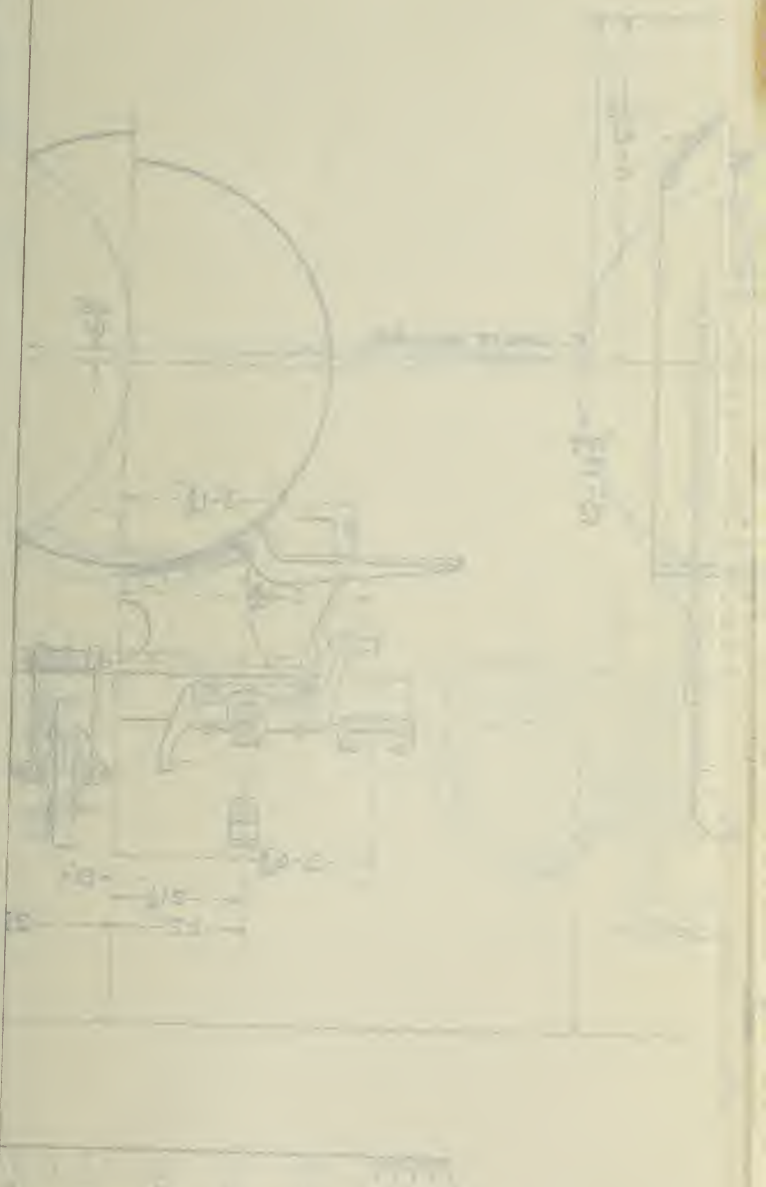


FIG. 918—ELEVATION, SHOWING POSITIONS OF INSTRUMENTS, LOCOMOTIVE No. 5266.



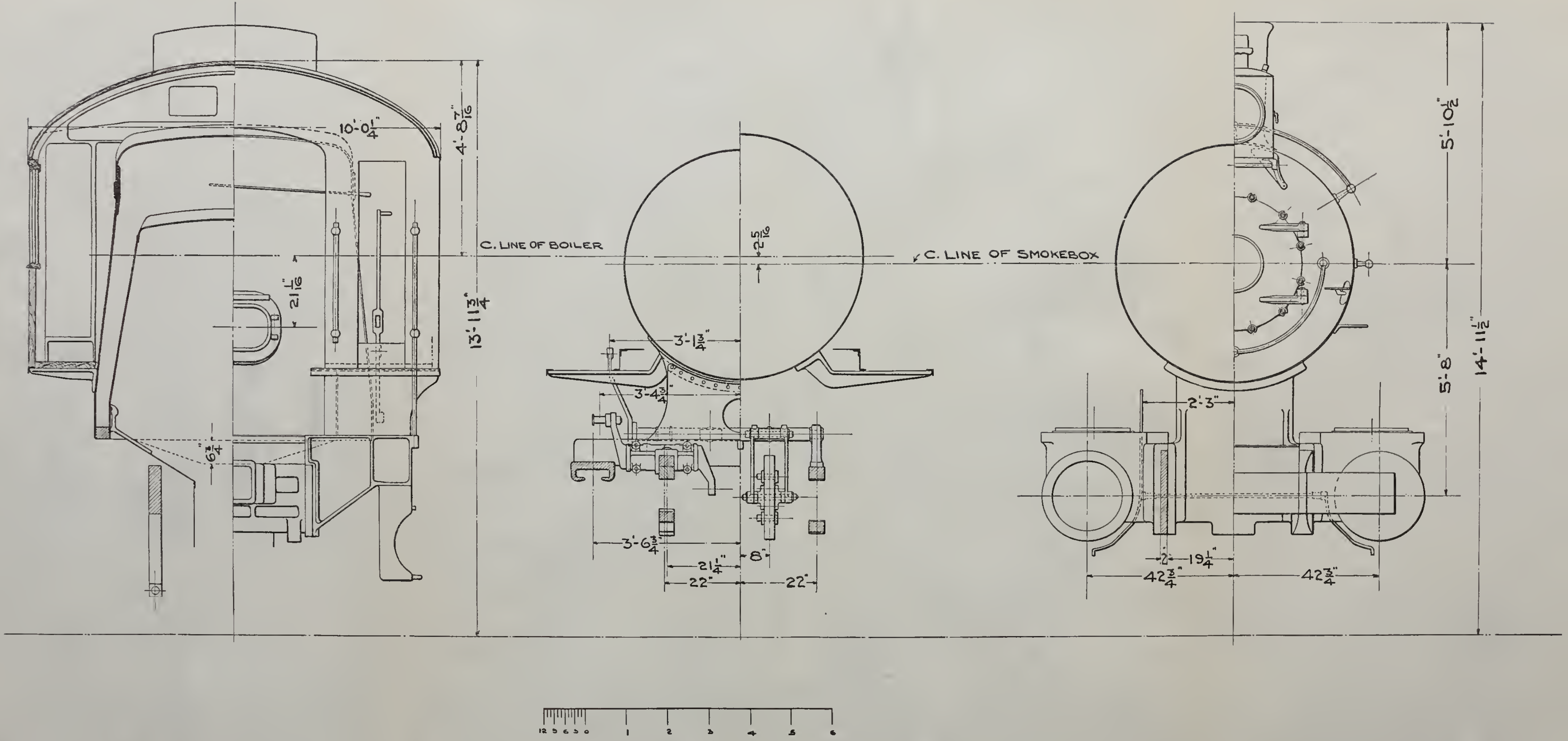
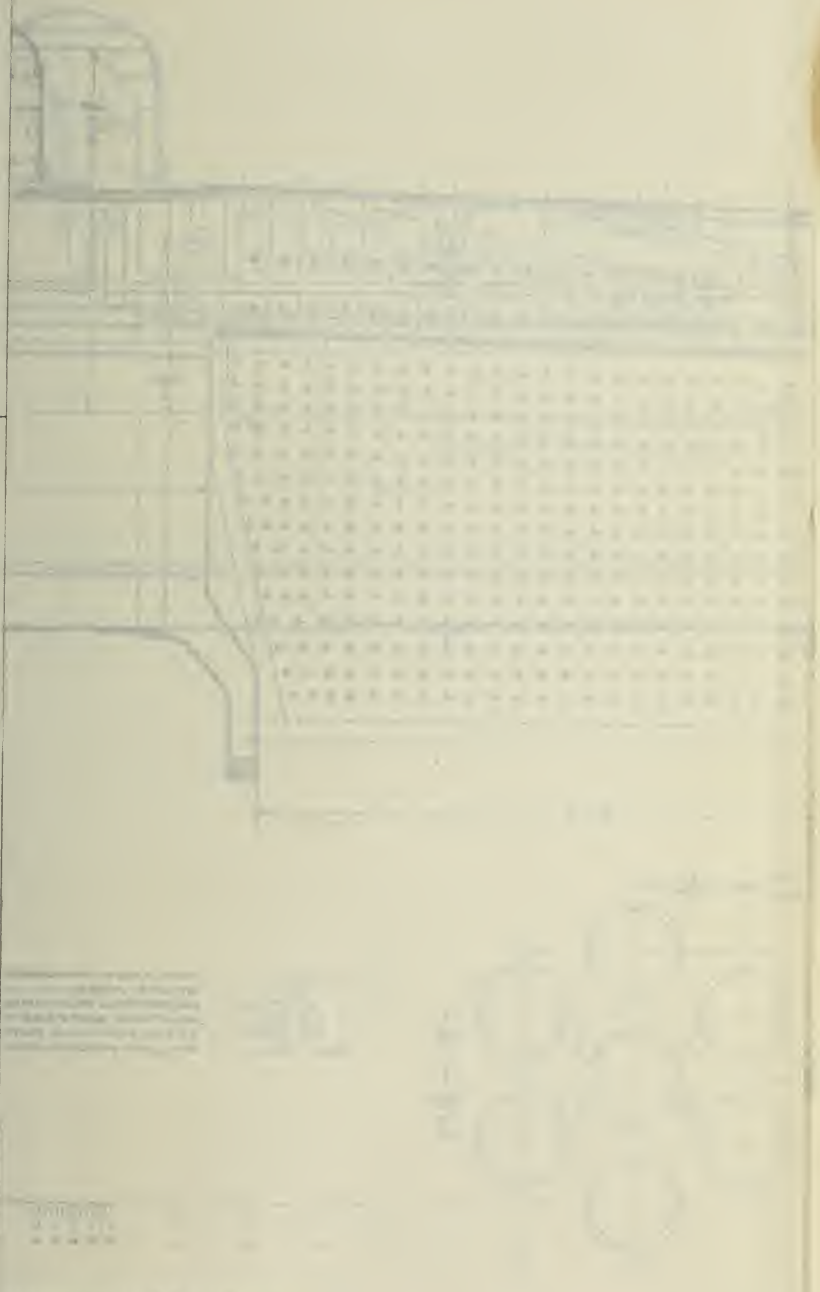


FIG. 919—CROSS SECTIONS, LOCOMOTIVE No. 5266.



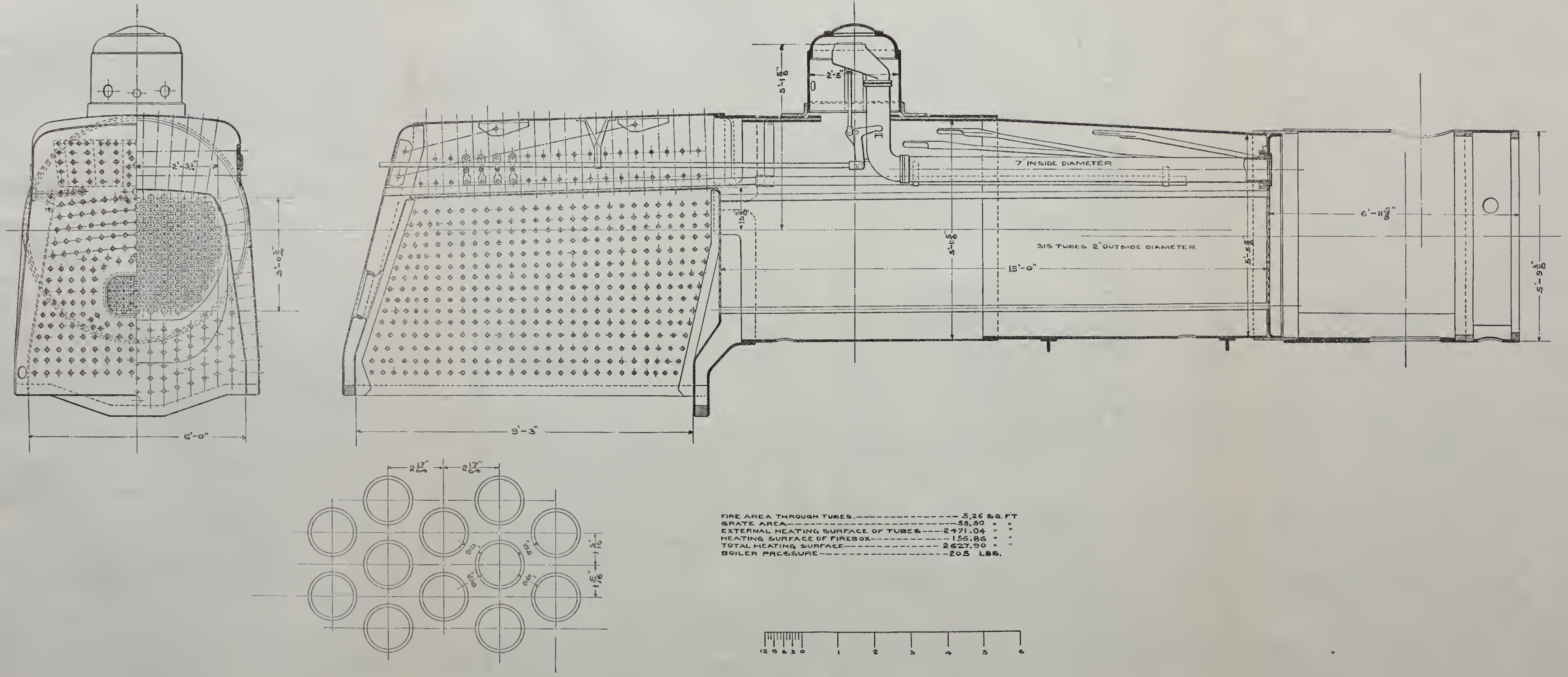


FIG. 920—BOILER, LOCOMOTIVE No. 5266.

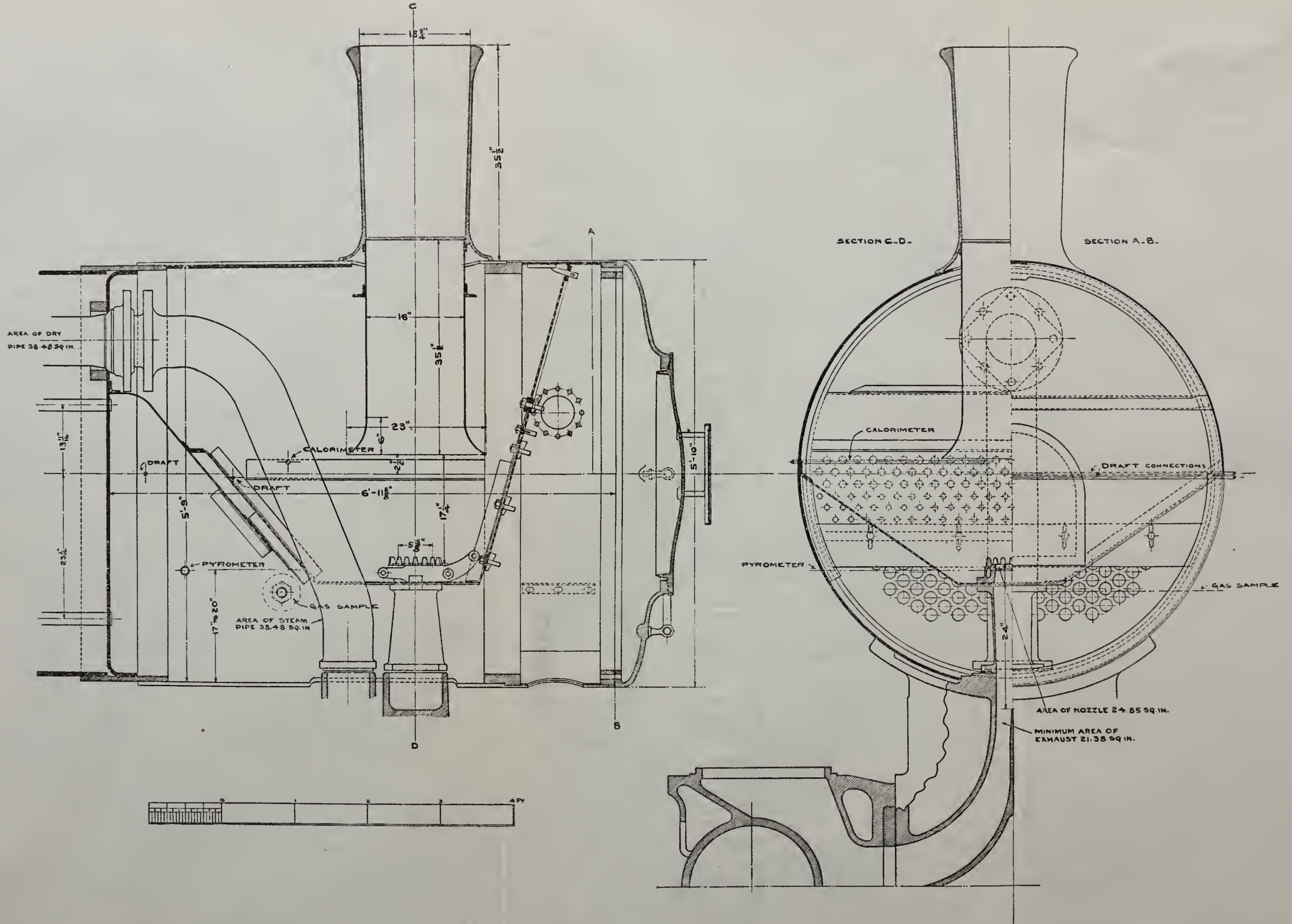
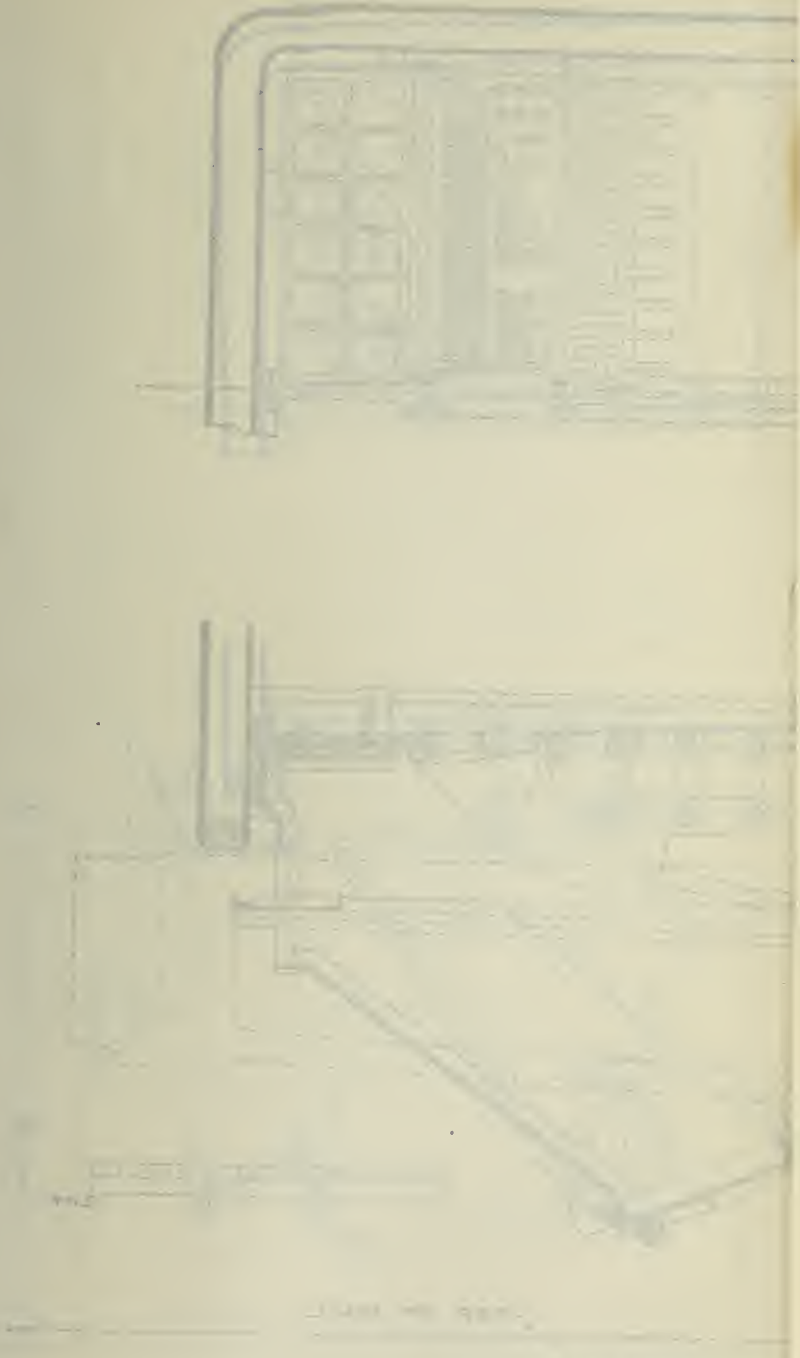


FIG. 921—FRONT END ARRANGEMENT, LOCOMOTIVE No. 5266.



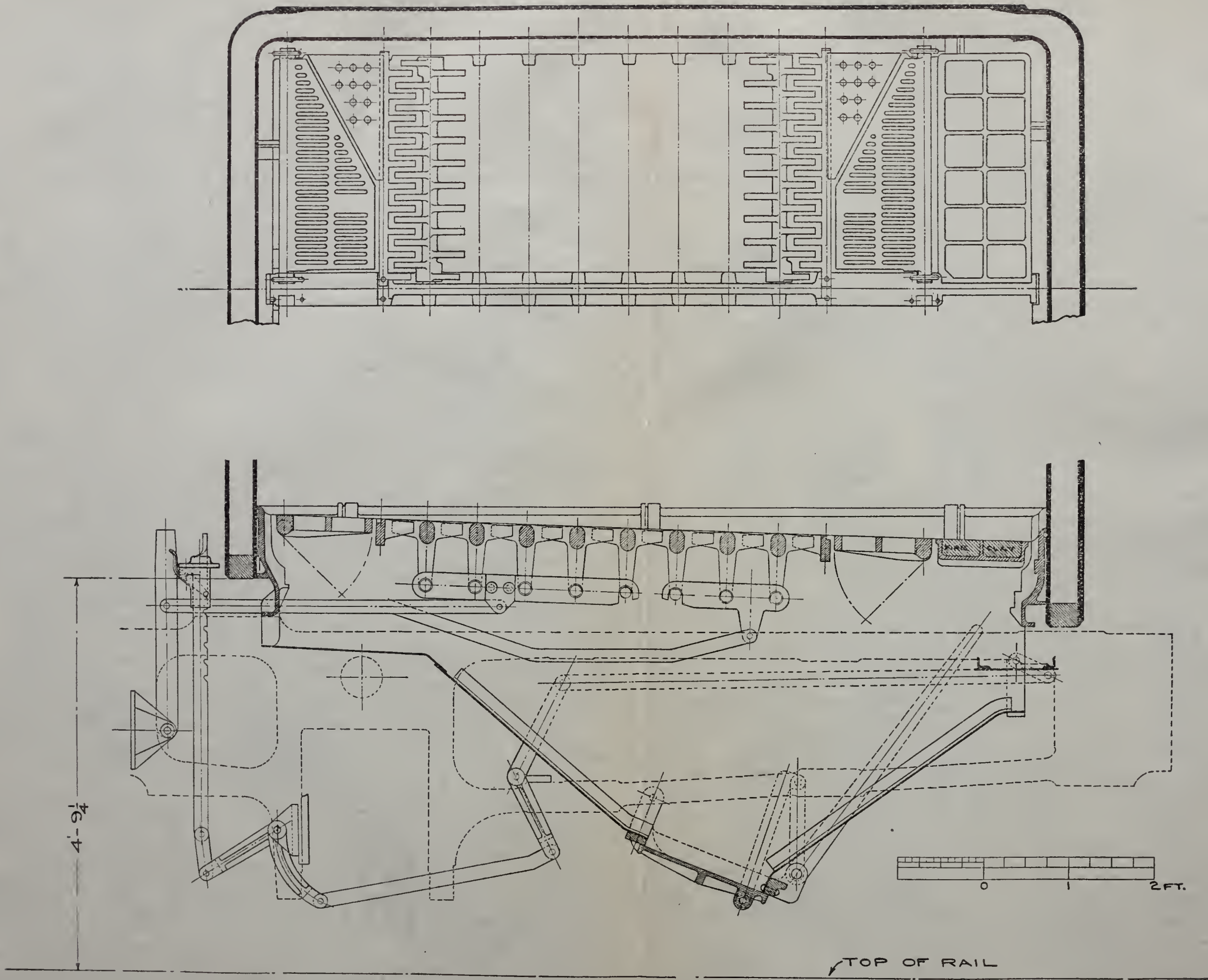


FIG. 922—GRATE AND ASH PAN, LOCOMOTIVE No. 5266.

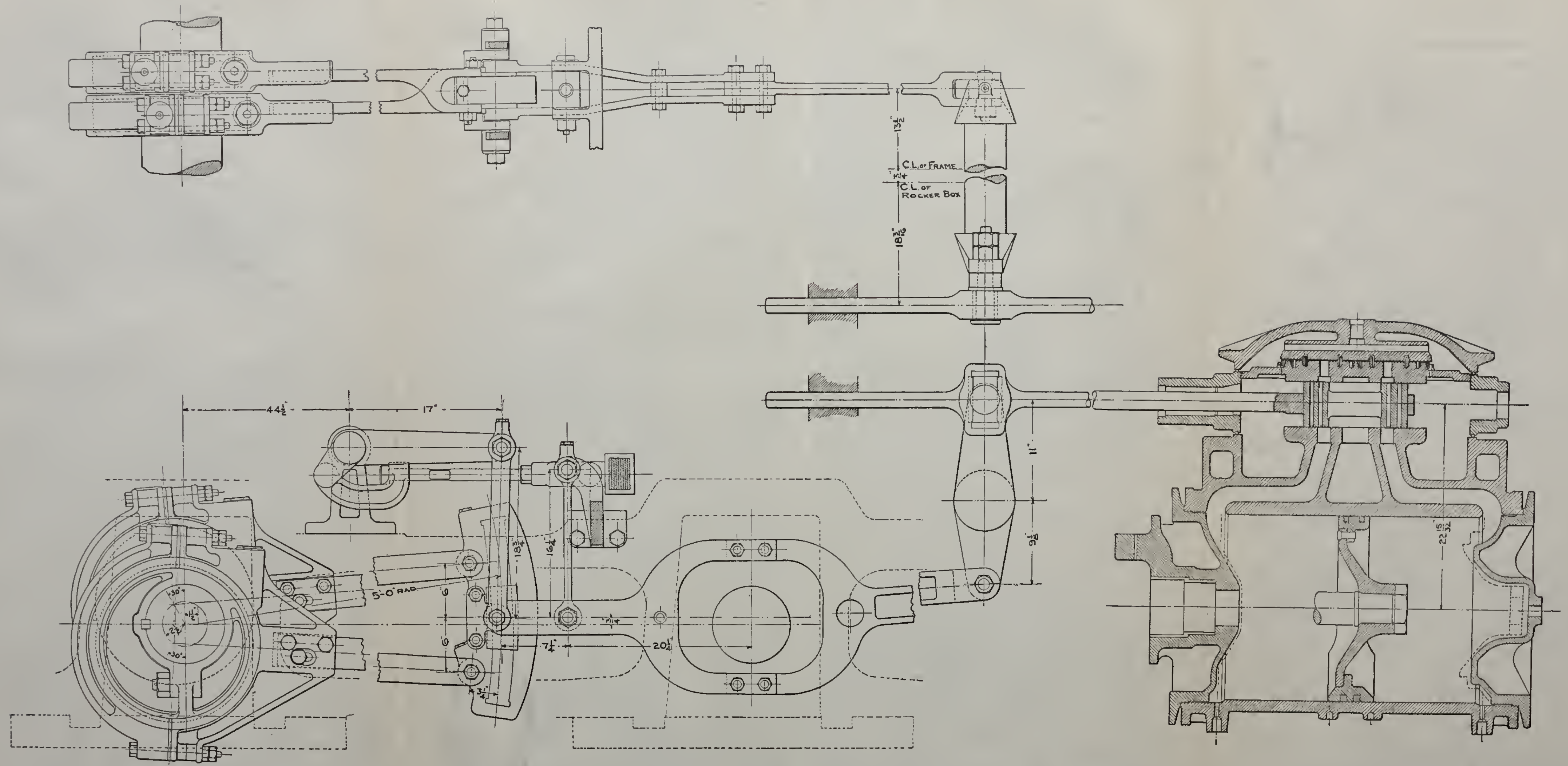


FIG. 923—VALVE GEAR, LOCOMOTIVE No. 5266.

PENNSYLVANIA RAILROAD COMPANY

Locomotive Testing Plant

AT

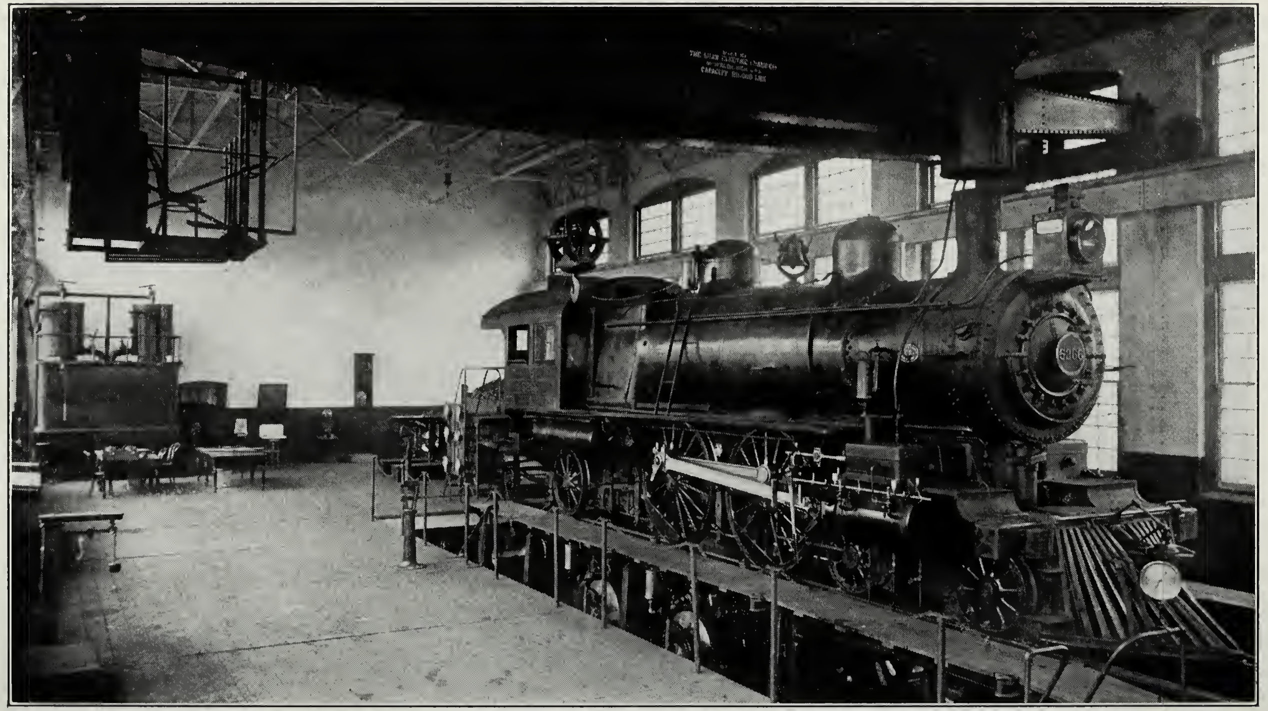
ALTOONA, PENNA.

BULLETIN No. 6 (Revised).

Formerly Bulletin No. 9.

HOLLOW BRICK ARCH

1912



LOCOMOTIVE 5266, CLASS E2a, IN POSITION FOR TEST.
Locomotive Testing Plant, Pennsylvania Railroad Company, Altoona, Pa.

LOCOMOTIVE TESTING PLANT.

TESTS WITH HOLLOW BRICK ARCH.

(Conclusions and recommendations on pages 6 and 7.)

INTRODUCTION.

1. For the improvement of combustion in locomotive fireboxes many devices have been suggested, one supposed to have merit being the hollow arch. This arch, in addition to maintaining a uniform furnace temperature, by its mass of heated bricks, also admits air above the fire to unite with the combustible gases. Combustion of these gases is, in many cases, but partly completed on account of the limited supply of air that is drawn through the grates, and it has been thought that, if additional air, passing through a hollow arch and becoming heated, could be mixed with the gases, combustion would be completed with beneficial results in economy of coal and emission of smoke. These expectations in regard to air admission were not realized, however, and the hollow arch did not show any marked advantages over an arch without air admission, but the advantages of the latter are brought out.

Description of the Arch.

2. A detail of the arch and the method of its application are shown in Fig. 6. As will be seen, the arch was formed of fire-clay segments $8\frac{3}{8}$ inches wide, made in two pieces and fitted together at the center of the span. These segments were hollow, having air passages through them. The arch was supported by angle irons held by studs in the firebox sides. Air was admitted to the air passages by holes drilled in the dead grate castings at the front of the firebox.

3. The combined area of the six air passages through the arch was about 60 square inches, or only 0.75 per cent. of the grate area. The total area of the openings in the dead grate below was 140 square inches.

Method of Making the Tests.

4. An arch of the hollow brick form arranged for air admission was applied to class "E2a" locomotive No. 5266, and with modifications, tried out in a number of tests, other tests being made on the same locomotive without an arch, all on the Locomotive Testing Plant, for the purpose of determining to what extent the amount of smoke could be reduced by such means, and whether and how much the evaporative efficiency of the boiler could be improved.

5. All of the tests with arch, with one exception, No. 900.16, were made at a speed of about 38 miles per hour, or nearly 160 revolutions per minute, with a cut-off of 25 per cent. and fully open throttle.

Modifications of Arch:

6. The first arch tried was the short form as shown in Fig. 4. The arch was next extended, as shown in Fig. 5, and in order to strengthen the end support for the arch it was necessary to cover 15 tubes.

7. The arch in the second form cracked between the air passages, and just after the test was completed the lower part of the arch separated completely and fell down. It was then rebuilt with new bricks in the form shown in Fig. 6, where it will be seen that the front end of the arch is brought much lower down and is well supported without covering any tubes. The supporting angles were increased in size to $2\frac{1}{2}$ by $2\frac{1}{2}$ inches, as lighter angles used in the first arches were found to sag between fastenings.

8. With this large arch, in two tests, the back end of the grate was blocked off so that the total grate area was reduced from the normal area of 55.5 to 39.5 sq. ft., or a reduction of about 29 per cent.

9. In three tests the air inlets to the arch were closed with fire-clay so that the arch would act as a simple arch without air admission.

10. When the air entered the firebox through the arch there was no means of determining what proportion of the air leaked through the joints between the arch segments. It was not possible to make these perfectly air tight.

11. One test, No. 900.16 with arch, and in which test the minimum amount of smoke was produced, was made at a lower speed and earlier cut-off than the others, and air was admitted to the firebox through the firedoor, which was kept on the first notch of the latch all of the time except when firing coal. No air was admitted through the arch in this case, while in the other tests the firedoor was kept closed when not firing coal.

12. The coal used was, in four tests, "Run of Mine Penn Gas," in seven tests, "Screened Penn Gas," and in one test "Scalp Level," see tables 1 and 2.

13. Penn Gas coal has about 36 per cent. volatile combustible material, and while a good coal it is smoky on account of the large amount of volatile matter. It is a coal which should show improved performance with an arch, the object of which is to maintain a high furnace temperature and thus consume all of the volatile gases as they are given off from a new charge of fuel.

14. Scalp Level coal is, on the other hand, a very low volatile coal for a bituminous coal, having as little as 16 per cent. of volatile combustible matter, or less than half that of the Penn Gas coal.

Results of Tests.

15. The results are given on table 2. Tests 900.2 and 952, made without any arch, are shown for comparison. Also in table 1 are given two additional tests, Nos. 900.1 and 951, without arch, for comparison of smoke readings.

16. The test results are plotted in Figs. 7, 8, 9 and 10. On these diagrams no curves are drawn through the points representing the brick arch tests, but the number of the test is given in each case opposite the points plotted. Other points are shown and curves drawn to show results obtained with the locomotive without any arch in the firebox, but fired with the same kind of coal.

Temperatures:

17. The arch covered the opening in the side of the firebox and prevented the use of a firebox pyrometer, except for two tests, and in these the temperature was about 15 per cent. higher with the arch than without. This is shown in Fig. 7.

Evaporation:

18. All of the tests with the arch and high volatile coals show results in evaporation per pound of coal above those obtained without the arch. There appears to be an improvement in evaporation with each increase in the length of the arch, and the best evaporation obtained was with the long arch without air admission through the arch.

19. Test 900.17 made with Scalp Level coal, with the arch and without air admission, gave an equivalent evaporation per pound of coal of 7.79 pounds, while a test of this coal, under like conditions but without an arch, shows an evaporation of 7.64 pounds, or practically the same result.

20. Scalp Level coal, however, is almost a semi-anthracite, and gives results fully equal to the screened Penn Gas coal when not burned too rapidly, but its evaporation falls off sharply when forced, on account of unburned coal lost through the stack.

21. From these tests, at rather a low rate of combustion for Scalp Level or a low volatile coal, it would appear that the steaming of this coal cannot be improved by the use of an arch.

Smoke:

22. Observations of the effect of the arch upon the smoke were made according to the Ringelmann method. The average smoke readings are given in the following, table 1:

TABLE 1, Smoke with Arch.

Test No.	Speed.	Cut-off.	Throttle.	Smoke.	Arch.			Coal.	Grate.
	Miles per hour.	Per cent.		In per cent. of Black.	With or without.	Length of —inches.	Blocked or open.	Screened or run of mine.	Small or full.
952	38	25	Full	46	Without	....	....	Screened	Full
900.2	38	25	Full	46	Without	....	....	R. of M.	Full
900.10	38	25	Full	46	With	33	Open	R. of M.	Full
900.11	38	25	Full	34	With	50	Open	R. of M.	Full
900.12	38	25	Full	28	With	62	Open	Screened	Small
900.13	38	25	Full	22	With	62	Open	Screened	Small
900.14	38	25	Full	20	With	62	Open	Screened	Full
900.15	38	25	Full	18	With	62	Blocked	Screened	Full
900.16	28	20	Full	2	With	62	Blocked	Screened	Full
900.17	38	25	Full	22	With	62	Blocked	R. of M.*	Full
951	28	20	Full	38	Without	....	....	Screened	Full
900.1	28	20	Full	34	Without	....	....	R. of M.	Full

* Scalp Level coal.

23. In test 900.16, as already stated (paragraph 11), there was very little smoke. No air was admitted through the arch, but the firedoor was partly open for air admission.

24. There is a decrease in the smoke accompanying the improved evaporation with each increase in the length of the arch, and a further slight decrease when there is no air admitted through the arch. In table 1, the per cent. of black smoke decreases from 46 to 18 per cent. with increases in the length of arch.

25. By the use of the arch the high volatile coal shows smoke four per cent. less black than does the low volatile coal under the same conditions of running.

Conclusions.

Evaporation:

26. The use of the brick arch, with a high volatile coal, such as Penn Gas, results in an increased evaporation, representing an economy in coal of from 12 to $13\frac{1}{2}$ per cent., the indication being that the hollow arch has no advantage over the solid one. (Paragraph 18.)

27. With a low volatile coal, such as Scalp Level, the arch does not appear to be of much benefit. (Paragraph 21.)

Smoke:

28. The admission of air through the arch does not appear to decrease the amount of smoke as obtained with the solid arch. (Paragraph 24.)

29. The smoke from a smoky coal, such as Penn Gas coal, can be reduced by the use of the arch so that it is less than the smoke from a low volatile coal without an arch, but it cannot be made so little as was obtained with low volatile briquettes without an arch. (Paragraph 25.)

General Conclusions:

30. The best results were obtained with the long arch and with air admitted to the firebox through the firedoor. The increase in economy and decrease in smoke followed closely the increase in the length of the arch.

Recommendations.

31. To reduce the amount of black smoke and to improve the economy of the boiler on locomotives where there is con-

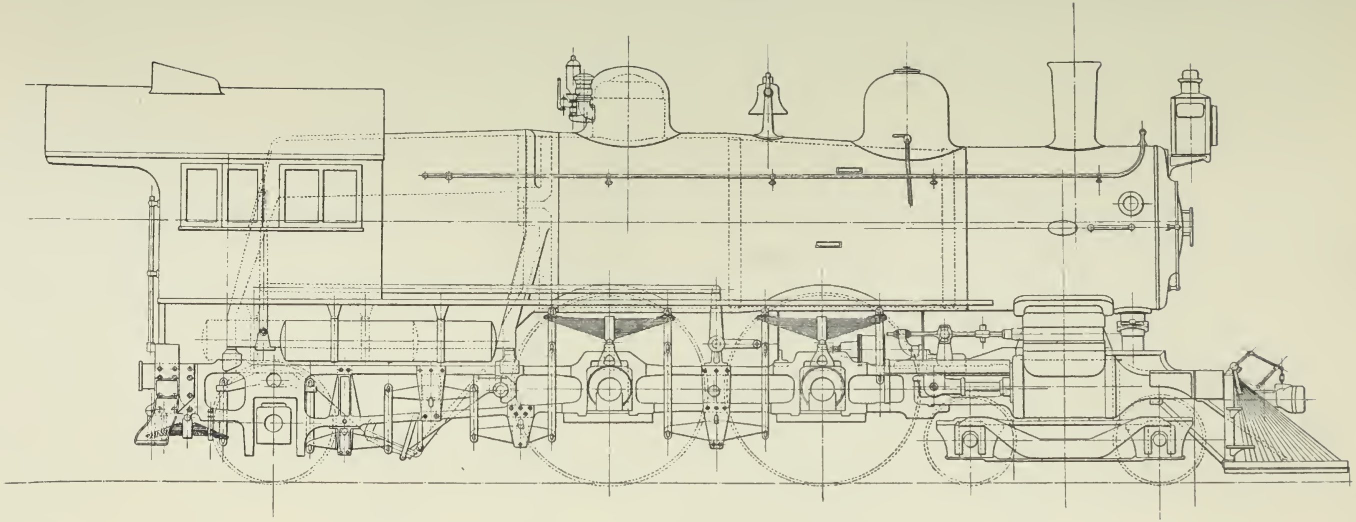
tinuous firing, as on long runs, a solid arch of a length greater than one-half of the firebox should be provided.

32. The reduction of smoke and the saving in fuel depend upon the service in which the locomotive is operated, and this as well as the maintenance of the arch should be given consideration, so as to save the expense of the arch when it is known there can be no material saving by its use.

C. D. YOUNG,
Engineer of Tests.

APPROVED:
J. T. WALLIS,
Genl. Supt. Motive Power.

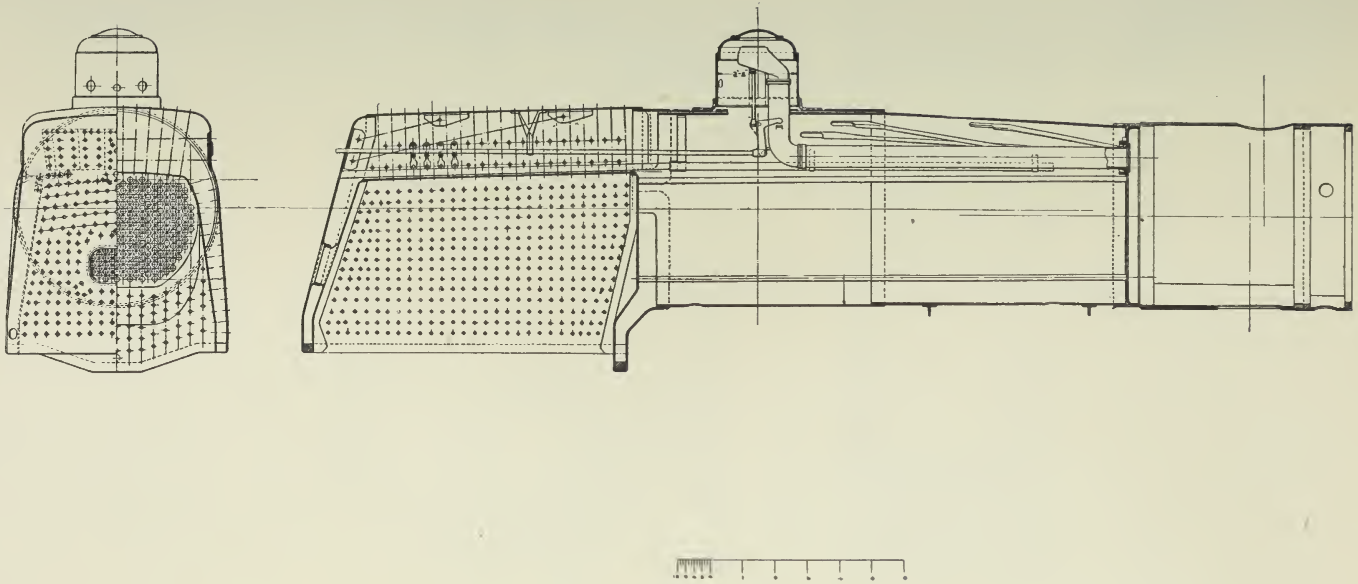
TEST DEPARTMENT,
ALTOONA, PENNA.,
January 28, 1912.



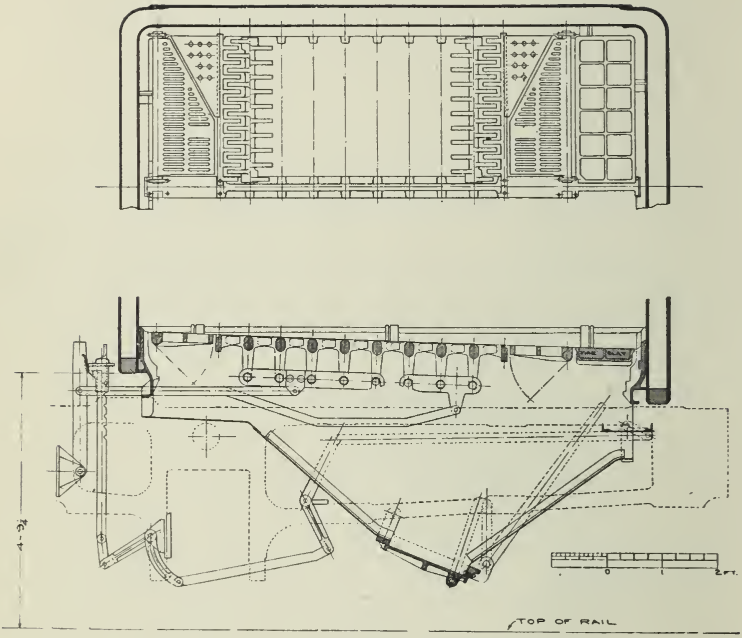
GENERAL ARRANGEMENT OF LOCOMOTIVE.
Fig. 1.

GENERAL DIMENSIONS OF LOCOMOTIVE (CLASS E2a)

Total weight in working order, pounds	184,167
Weight on drivers, in working order, pounds	110,000
Cylinder (simple) size, inches	$20\frac{1}{2}$ x 26
Diameter of driving wheels, inches	80
Firebox heating surface, square feet	156.86
Heating surface of tubes (water side), square feet	2,471.04
Total heating surface (based on water side tubes), square feet	2,627.90
Total heating surface (based on fire side tubes), square feet	2,319.26
Grate area, square feet	55.5
Boiler pressure, pounds per square inch	205
Valves, type	Wilson double ported, slide
Valve gear	Stephenson
Firebox, type	Wide, Belpaire
Number of tubes	315
Outside diameter of tubes, inches	2
Length of tubes, inches	180



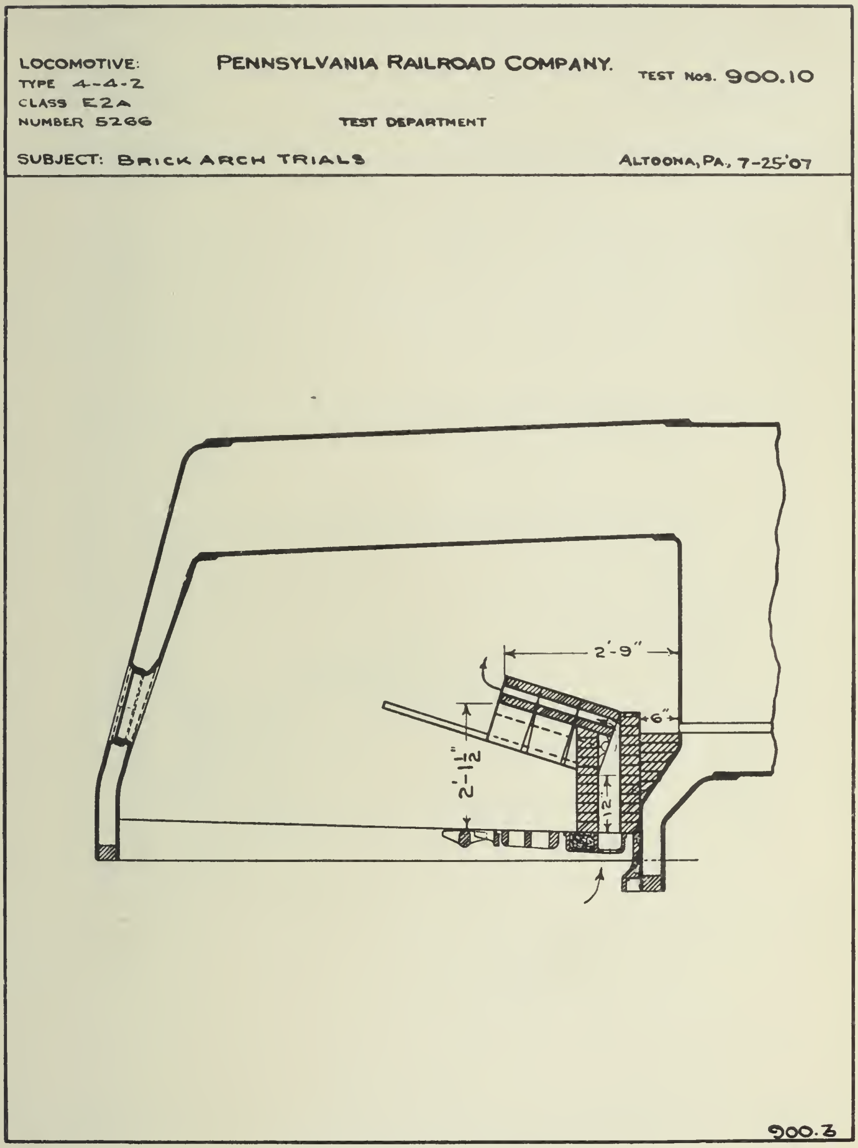
THE BOILER.
Fig. 2.



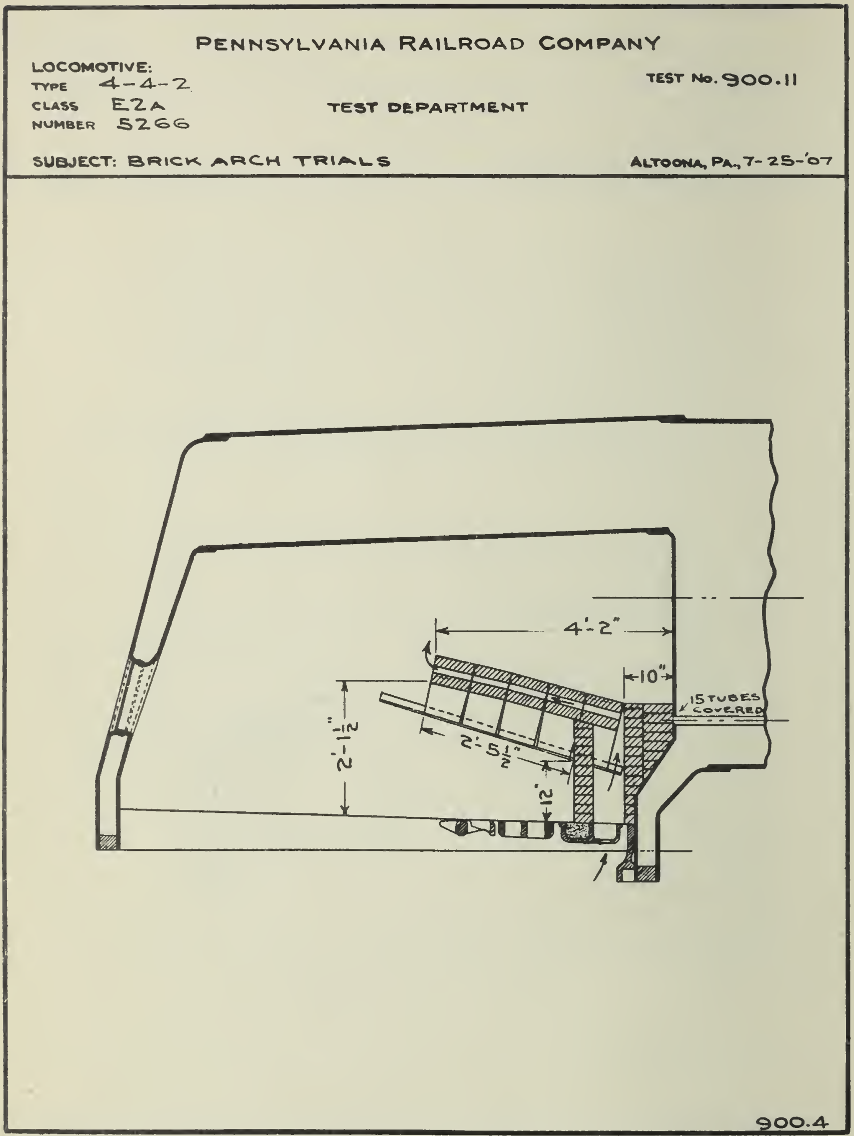
THE GRATE.

It can be shaken in four separate sections. There is a drop grate at the front and rear and a dead grate at the forward end.

Fig. 3.



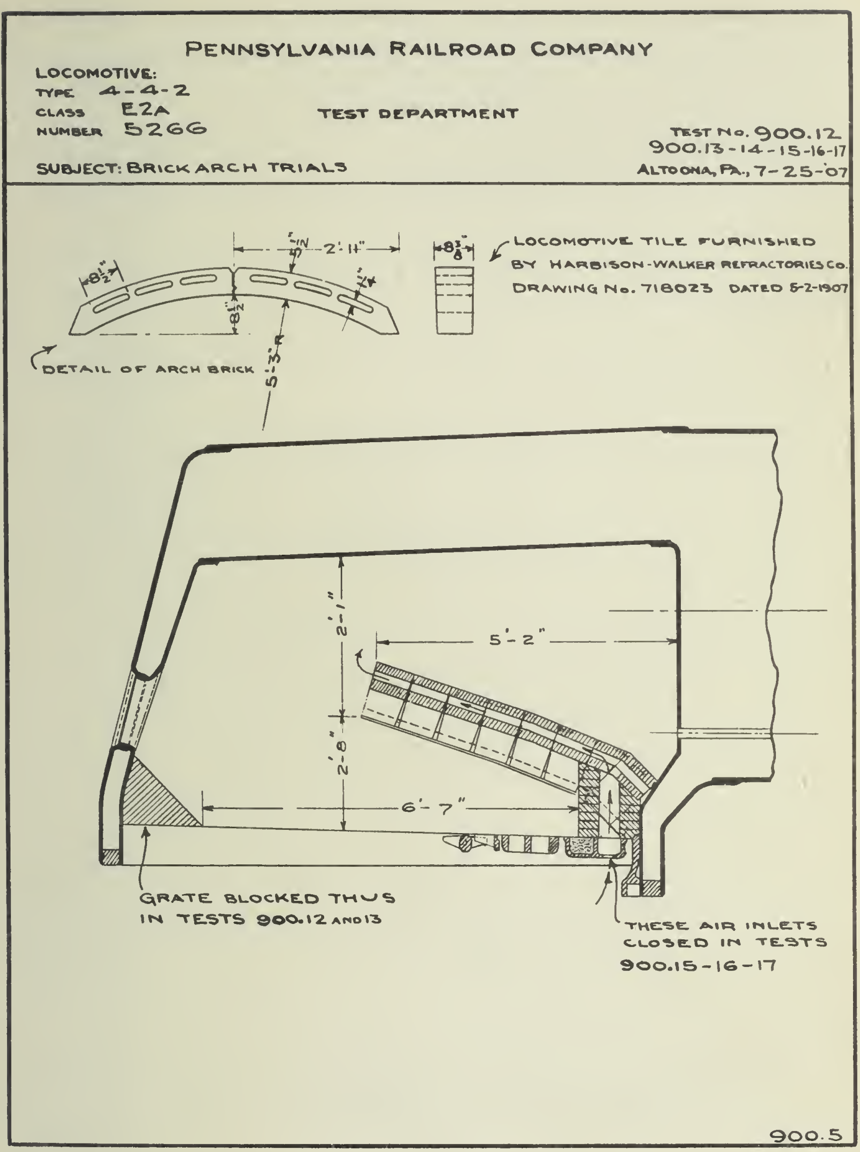
THE FIRST OR SHORT FORM OF ARCH.
This arch was too small to show much improvement in evaporation or smoke.
Fig. 4.



THE SECOND FORM OF ARCH.

It is longer than the first form, and while the lower row of tubes was covered it gave better results than the first arch.

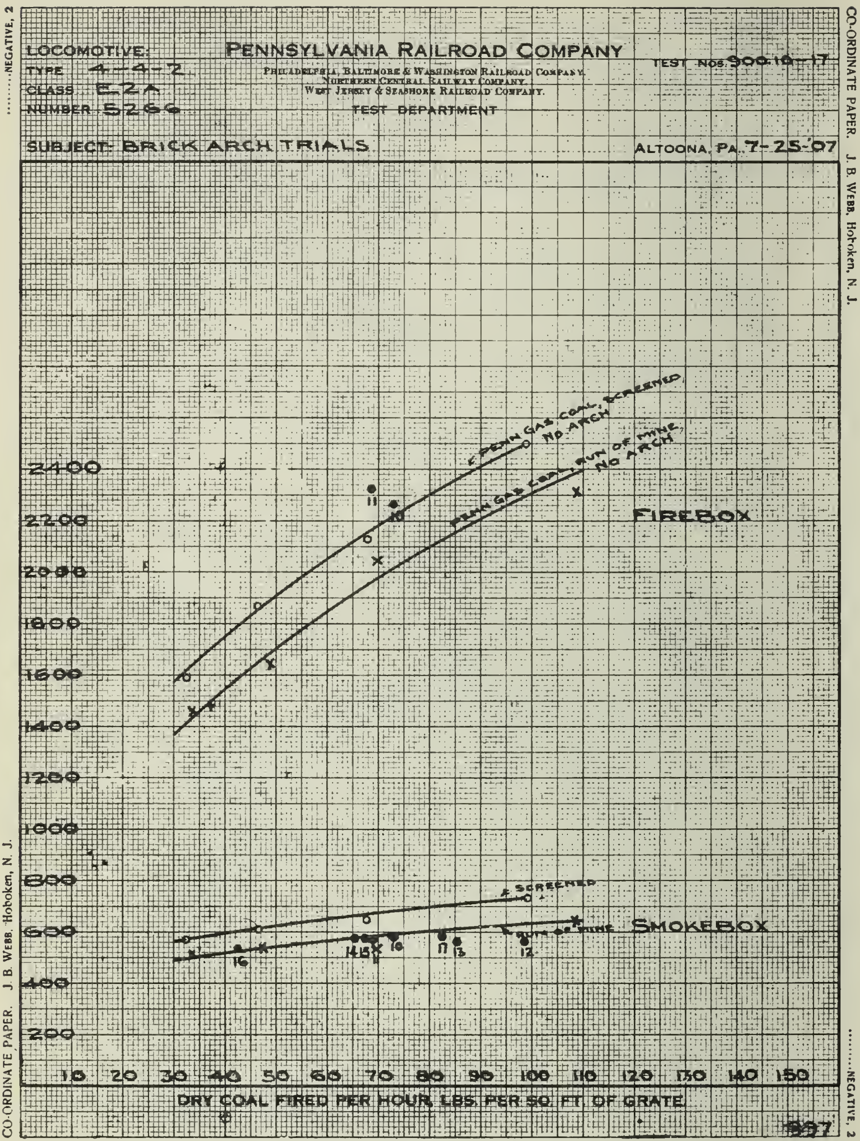
Fig. 5.



THE LONG ARCH WITH THE FRONT END DEPRESSED TO CLEAR THE TUBES.

This arch was used with the air inlets both closed and open and with part of the rear portion of the grate covered with firebrick. This arch shows the best results and there was least smoke when the air passages were closed.

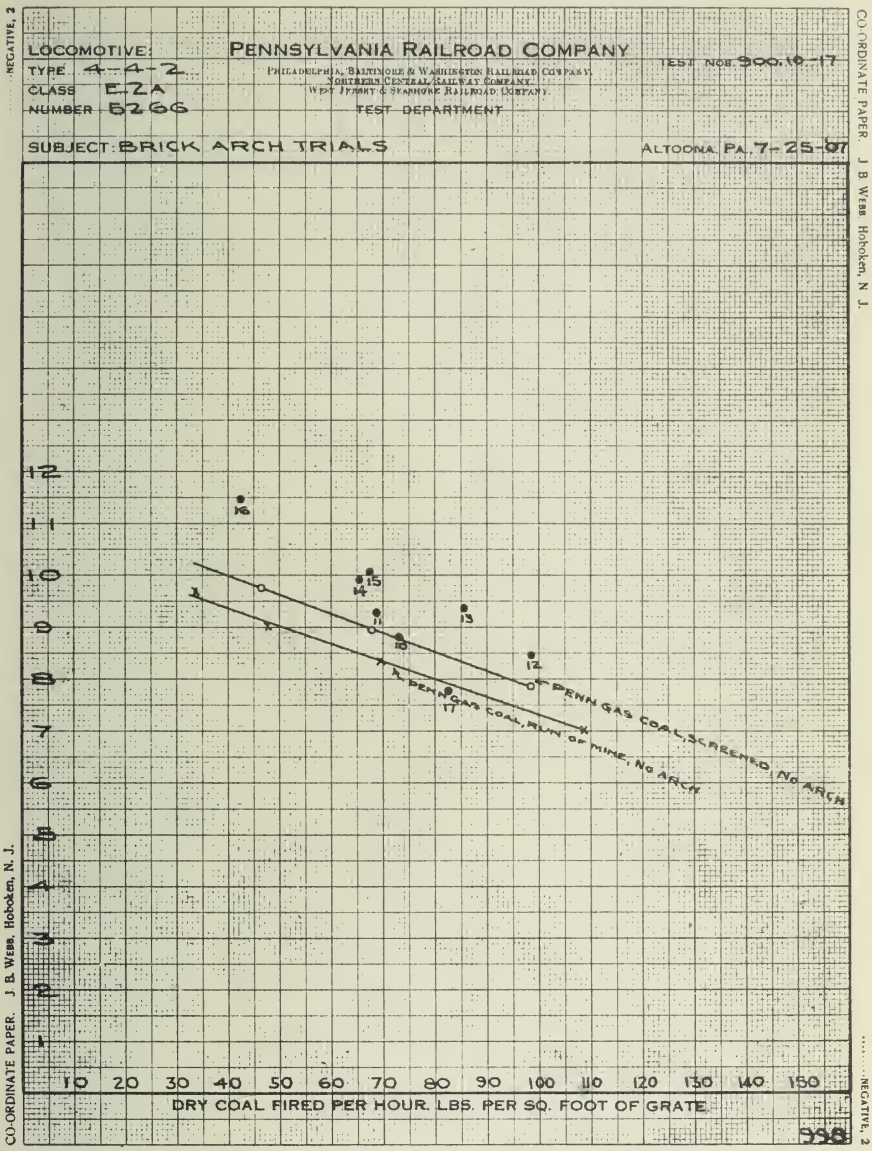
Fig. 6.



TEMPERATURE OF FIREBOX AND SMOKEBOX.

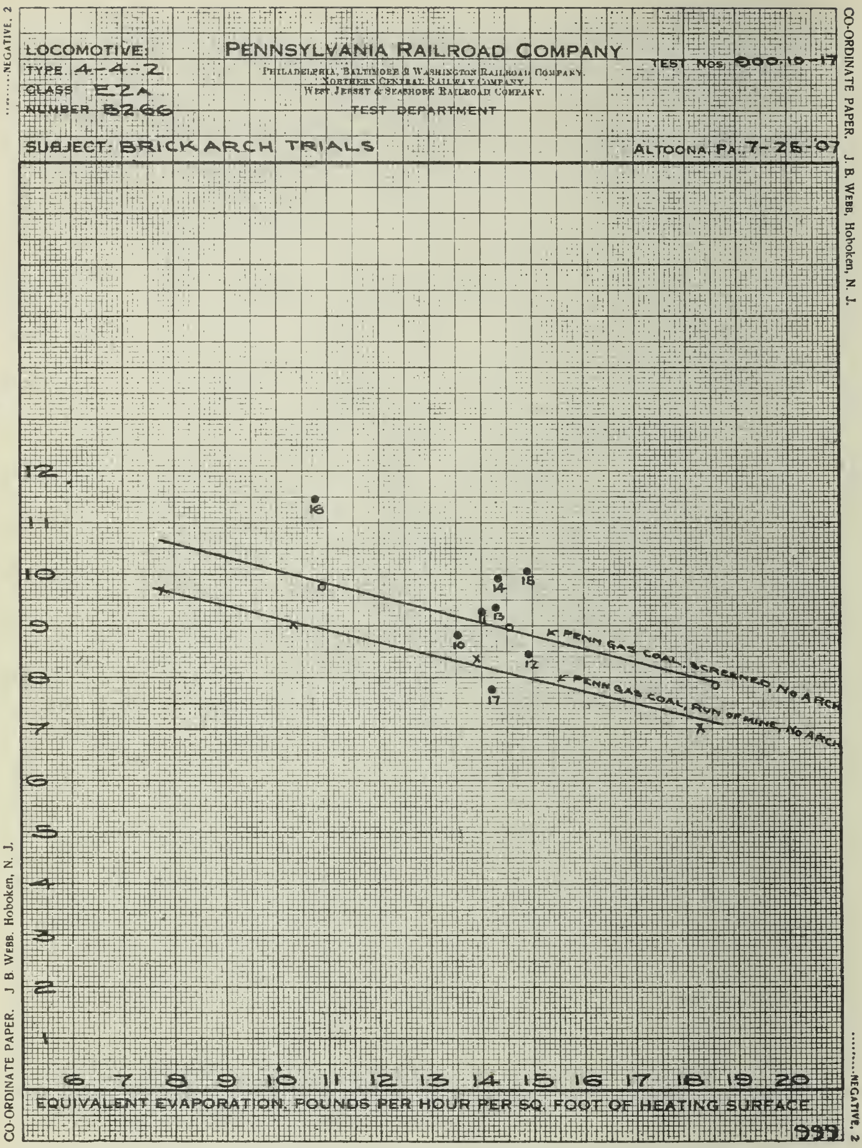
The points with numbers are arch tests. The other points and curves are for tests without arch. Tests 10 and 11 were with run of mine coal, and they show a temperature of firebox about 15 per cent. above that without an arch.

Fig. 7.

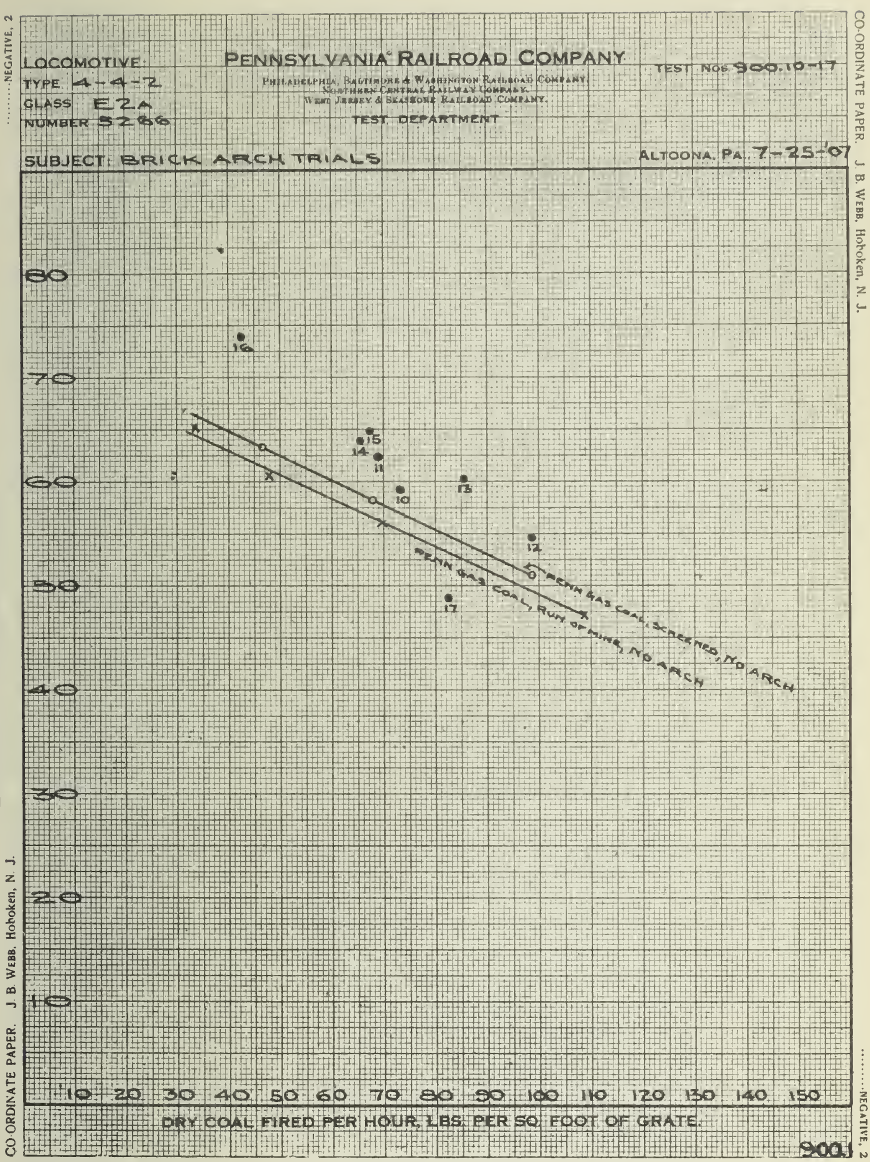


EVAPORATION PER POUND OF DRY COAL AND COAL FIRED PER SQUARE FOOT OF GRATE.
The numbered points represent Arch Tests. Those without numbers and the curves are for tests without an arch in the Firebox. Tests 10 and 11 were with run of mine coal, 12 to 16 with screened coal, and 17 was a different coal from the others.

Fig. 8.



EVAPORATION PER POUND OF COAL AND RATE OF EVAPORATION.
The evaporation is about 12 per cent. more per pound of coal with the arch in its best form. Note the low evaporation (point 17) with a low volatile coal.
Fig. 9.



BOILER EFFICIENCY.

The efficiency is increased with the arch, as shown by the points with numbers. Without the arch, the efficiency is from 51 to 64 per cent. With the arch it is from 55 to 74 per cent.

Fig. 10.

M. P. 894A
8 x 10½

7 6 1907

PENNSYLVANIA RAILROAD COMPANY

Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company

TEST DEPARTMENT

AVERAGE RESULTS OF LOCOMOTIVE TESTS

LOCOMOTIVE:
TYPE 4-4-2
CLASS E2A
NUMBER 5266

TEST NOS., 952, 900.2
900.10 TO 17

SUBJECT: BRICK ARCH TRIALS

ALTOONA, PA., 8-19-'07

	DRIVING WHEELS	
1	Number of Pairs	2
2	Approx. Diameter, inches	80
	ENGINE TRUCK WHEELS	
14	Number	4
15	Diameter, inches	36
	TRAILING WHEELS	
16	Diameter, inches	50
	WHEEL BASE, FEET	
17	Driving Wheel Base	7.42
18	Total Wheel Base	30.85
19	Gage of Wheels	56.13
	WEIGHT OF ENGINE WITH WATER AT 2D. GAGE COCK AND NORMAL FIRE, POUNDS	
20	On Truck	37167
21	" 1st Drivers	53334
22	" 2d "	56667
23	" 3d "	—
24	" 4th "	—
25	" 5th "	—
26	" Trailers	37000
27	Total	184167
28	" on Drivers	110001
	CYLINDERS	
	Diam. and Stroke, H. P	20.5X26
	" " " L. P	—
	CLEARANCE IN PER CENT. OF PISTON DISPLACEMENT	
40	H. P. Right, Head End	12.7
41	" " Crank "	12.1
42	" Left, Head "	12.4
43	" " Crank "	11.9
44	L. P. Right, Head "	—
45	" " Crank "	—
46	" Left, Head "	—
47	" " Crank "	—
	RECEIVER, CUBIC FEET	
48	Volume Right Side	—
49	" Left "	—
	STEAM PORTS, INCHES	
50	H. P. Admission, Length	19.87
51	" " Width	1.48
58	L. P. " Length	—
59	" " Width	—
66	H. P. Exhaust, Length	19.84
67	" " Width	2.98
70	L. P. " Length	—
71	" " Width	—

	PISTON RODS, DIAMETER INCHES	
74	High Pressure	3.472
76	Low "	—
	TAIL RODS, DIAMETER, INCHES	
78	High Pressure	—
80	Low "	—
	VALVES	
82	Type	DOUBLE PORTED BAL. SLIDE
83	Design	AMERICAN BAL. VALVE CO.
84	Per Cent. Balanced	75.7
85	Type of Valve Motion	STEPHENSON
	GREATEST VALVE TRAVEL	
86	High Pressure, inches	7.0
88	Low " "	—
	OUTSIDE LAP OF VALVE	
90	High Pressure, inches	1.5
94	Low " "	—
	INSIDE LAP OF VALVE	
98	High Pressure, inches	NEGATIVE .16
102	Low " "	—
	BOILER	
113	Type	BELPAIRE WIDE FIRE-BOX
114	Outside Diam. 1st Ring	67.0
	TUBES	
115	Number	315
116	Outside Diam., inches	2.0
	Pitch "	2.625
118	Length Between Tube Sheets, inches	179.78
119	Total Fire Area, sq. ft.	5.26
124	Boiler Pressure, pounds	205
	SUPERHEATER	
125	Number of Tubes	—
126	Outside Diam. " inches	—
128	Length of " "	—
	FIREBOX, INSIDE, INCHES	
132	Length	114.0
133	Width	68.0
137	Air Inlets to Ashpan, sq. ft.	6.3
	GRATES	
144	Type	ROCKING FINGER.
145	Grate Area, sq. ft.	55.5
146	Area of Dead Grates	6.0

	HEATING SURFACE, SQUARE FEET	
154	Of the Tubes, Water Side	2471.04
155	" " " Fire "	2162.40
156	" " Firebox, " "	156.86
157	" " Superh'r, " "	—
*158	Total, Based on " "	2319.26
159	" " " " " of Firebox and Water Side of Tubes	2627.90
	BOILER VOLUME WITH WATER SURFACE AT LEVEL OF 2D GAGE COCK	
160	Water Space, cu. ft.	338.6
161	Steam " " "	109.9
	EXHAUST NOZZLE	
162	Double or Single	SINGLE
163	Size, inches	5.625
167	Area, sq. inches	24.85
	REVERSE LEVER	
168	H. P. Notches Forward of Center	15
169	L. P. Notches Forward of Center	—
	RATIOS	
171	Heating Surface (158) to Grate Area (145)	41.79
172	Fire Area Thru Tubes (119) to Grate Area (145)	.09
173	Firebox Heating Surface (156) to Grate Area (145)	2.83
174	Tube Heating Surface (155) to Fire Box Heating Surface (156)	13.79

THE ABOVE ITEMS SHOW THE NORMAL DIMENSIONS OF THE LOCOMOTIVE WITH FULL GRATE AREA

*USED IN CALCULATIONS

DIMENSIONS OF LOCOMOTIVE 5266.

M. P. 894 A—Sixth Sheet
8 x 10½

7 6 1907

PENNSYLVANIA RAILROAD COMPANY

Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company

TEST DEPARTMENT

AVERAGE RESULTS OF LOCOMOTIVE TESTS

LOCOMOTIVE:
TYPE 4-4-2
CLASS E2A
NUMBER 5266

FUEL: PENN GAS AND SCALP LEVEL COAL

SUBJECT: BRICK ARCH TRIALS

ALTOONA, PA., 8-19-07

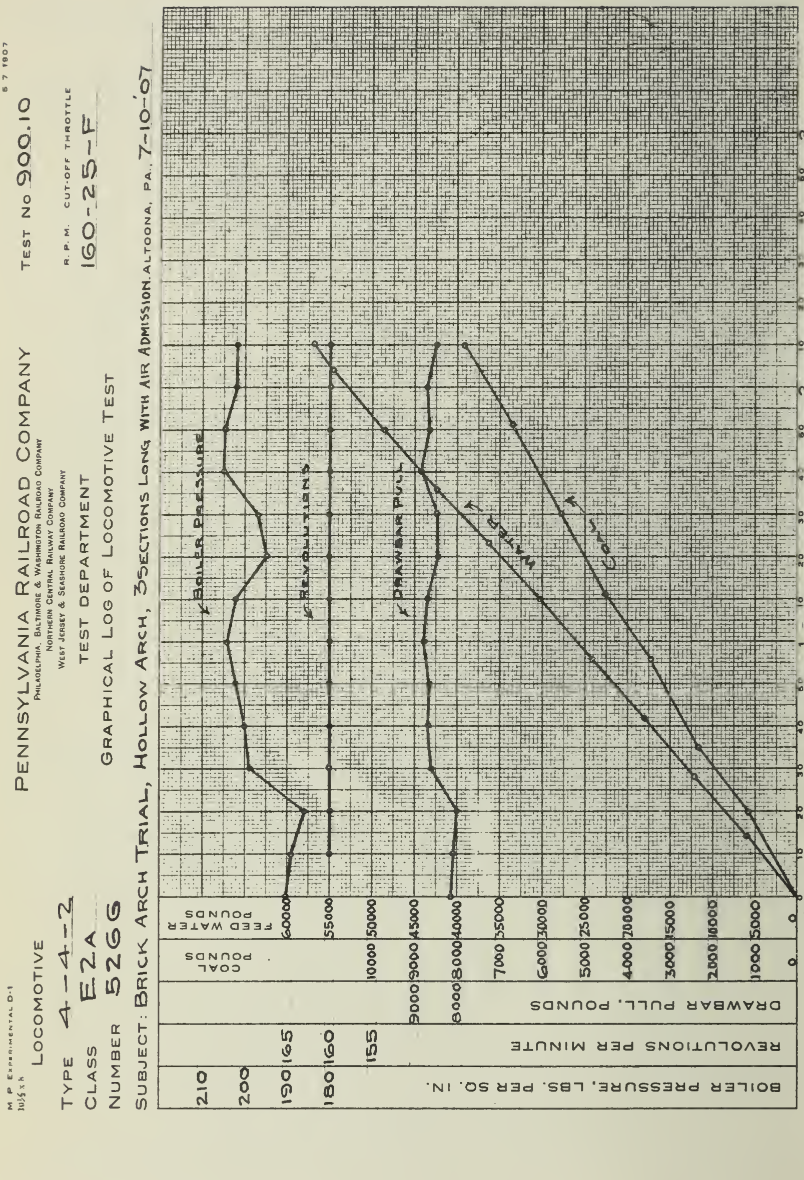
TEST NUMBER	RUNNING CONDITIONS						BOILER PERFORMANCE				
	TEST DESIGNATION	Duration of Test, Hours	Miles per Hour	Throttle Opening, Full or Partial	Actual Cut-off Per Cent., H. P. Cylinders	ARCH OR NO ARCH	Pressure in Boiler, Lbs. per Sq. Inch	Draft in Smoke Box, Inches of Water	Draft in Ash Pan, Inches of Water	Calorific Value of Dry Fuel, B.T.U. per Lb.	Cinders Collected in Smoke Box, Pounds per Hour
	R. P. M. Cut-off Throttle	196	199	203	266 to 271	.	217	222	225	248	238
952	160-25-F	2.50	38.02	FULL		No ARCH	201.8	3.8	.2	14864	48
900.2	160-25-F	2.50	37.65	"		No ARCH	201.5	4.7	.2	14360	100
900.10	160-25-F	2.17	37.65	"		ARCH	198.4	4.7	.2	14360	135
900.11	160-25-F	2.50	37.65	"		"	198.9	4.7	.2	14360	86
900.12	160-25-F	1.00	37.65	"		"	203.1	5.3	.2	14972	144
900.13	160-25-F	2.50	37.65	"		"	200.6	5.3	.2	14972	140
900.14	160-25-F	2.00	37.65	"		"	203.0	5.0	.2	14972	79
900.15	160-25-F	1.50	37.65	"		"	203.7	3.8	.2	14972	120
900.16	120-20-F	2.00	28.24	"		"	202.2	3.0	.1	14972	43
900.17	160-25-F	2.00	37.65	"		"	202.2	5.2	.2	15402	302

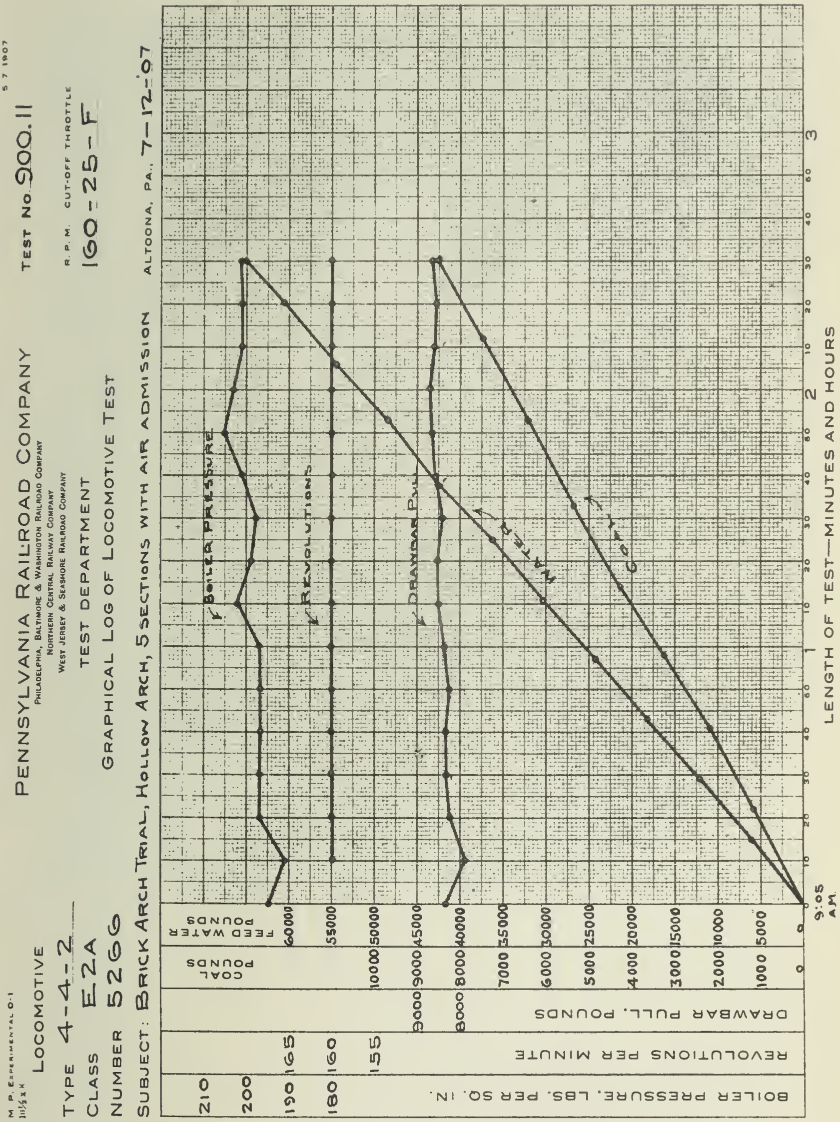
TEST NUMBER	BOILER PERFORMANCE									ENGINE PERFORMANCE	
				EQUIVALENT EVAPORATION FROM AND AT 212° F., POUNDS							
	Dry Fuel Fired per Hour, Pounds	Dry Fuel per Hour, Pounds per Sq. Ft. of Grate	Water Delivered to Boiler, Pounds per Hour	Per Hour	Per Hour per Sq. Ft. of Fire Heating Sur.	Per Pound of Dry Fuel	Boiler Horse Power (34½ U. of E.)	Efficiency of Boiler, Based on Fuel	SMOKE NUMBER	Pressure in Branch Pipe, Pounds per Sq. In.	Superheat in Branch Pipe, Degrees F.
	338	339	340	344	345	347	349	350		220	230
952	3768	67.89	27598	33764	14.56	8.96	978.7	58.22	2.3		
900.2	3864	69.62	26829	32232	13.90	8.34	934.3	56.09	2.3		
900.10	3567	72.95	26213	31384	13.53	8.80	909.7	59.19	2.3		
900.11	3357	68.65	26034	31144	14.06	9.28	902.7	62.41	1.7		
900.12	3905	98.86	27683	33045	14.92	8.46	957.8	54.57	1.4		
900.13	3374	85.42	26430	31579	14.26	9.36	915.3	60.38	1.1		
900.14	3201	65.46	26546	31720	14.32	9.91	919.4	63.93	1.0		
900.15	3286	67.20	27684	33011	14.90	10.05	956.9	64.83	.9		
900.16	2080	42.54	20008	23838	10.76	11.46	691.0	73.93	.1		
900.17	4037	82.56	26362	31446	14.20	7.79	911.5	48.85	1.1		

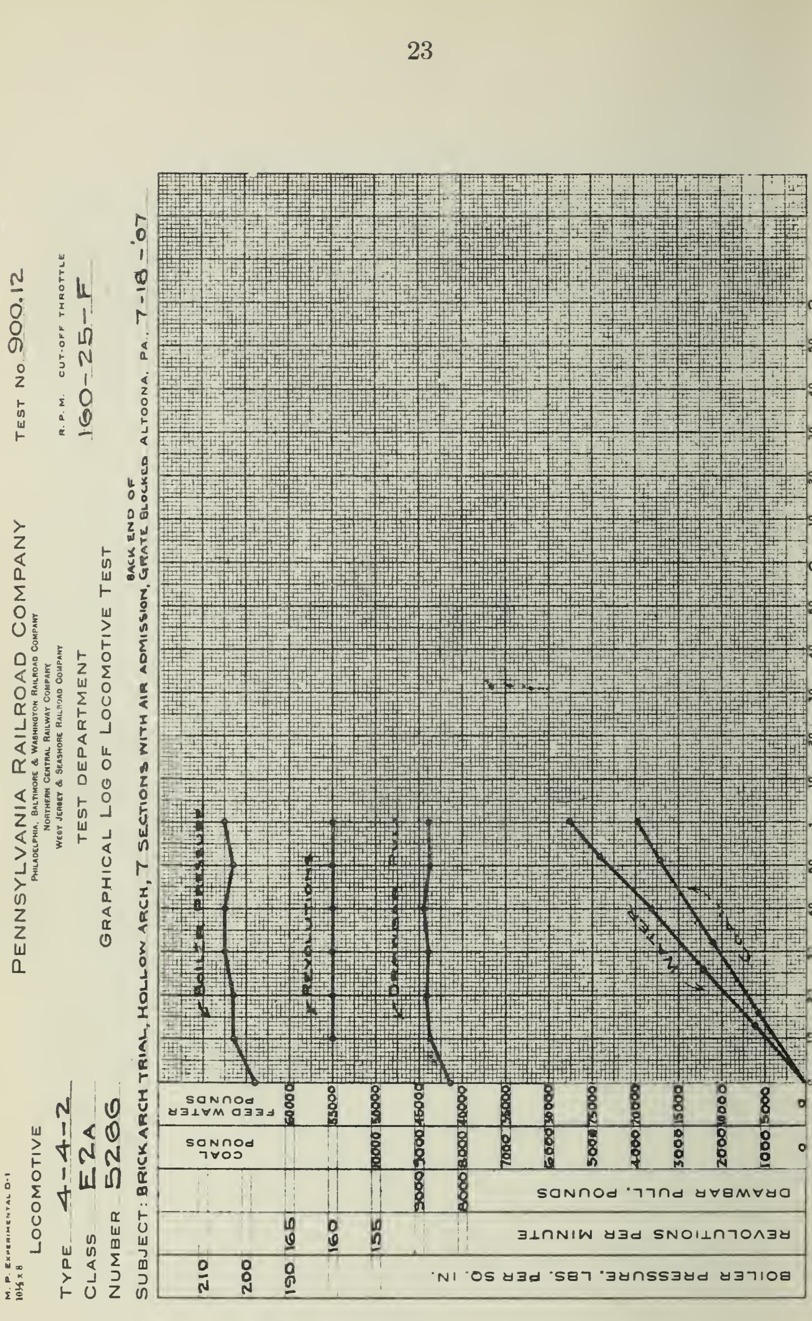
TEST NUMBER	ENGINE PERFORMANCE					LOCOMOTIVE PERFORMANCE						
	Dry Steam to Engines, Pounds per Hour	Indicated Horse Power	Dry Fuel per Indicated Horse Power Hour, Pounds	Dry Steam per Indicated Horse Power Hour, Pounds	LENGTH OF ARCH	Drawbar Pull, Pounds	Dynamometer or Drawbar Horse Power	Dry Fuel per Dynamom. Horse Power Hour, Pounds	Dry Steam per Dynamom. Horse Power Hour, Pounds	Machine Efficiency of Locomotive, Per Cent.	Thermal Efficiency of Locomotive, per Cent., (Based on Fuel)	KIND OF COAL
	214	379	380	381		265	383	384	385	398	399	
952					—	8768	888.9	4.24	30.74		4.04	PENN GAS
900.2					—	8947	898.5	4.30	29.55		4.12	" "
900.10					2'-9"	8579	861.5	4.14	30.12		4.28	" "
900.11					4'-2"	8492	852.8	3.94	30.22		4.50	" "
900.12					5'-2"	8822	885.9	4.41	30.92		3.85	" "
900.13					5'-2"	8633	866.9	3.89	30.18		4.37	" "
900.14					5'-2"	8762	879.9	3.64	29.86		4.67	" "
900.15					5'-2"	8904	894.1	3.68	30.65		4.62	" "
900.16					5'-2"	7783	586.1	3.35	31.28		4.79	" "
900.17					5'-2"	8998	903.6	4.47	28.86		3.70	SCALP LEVEL

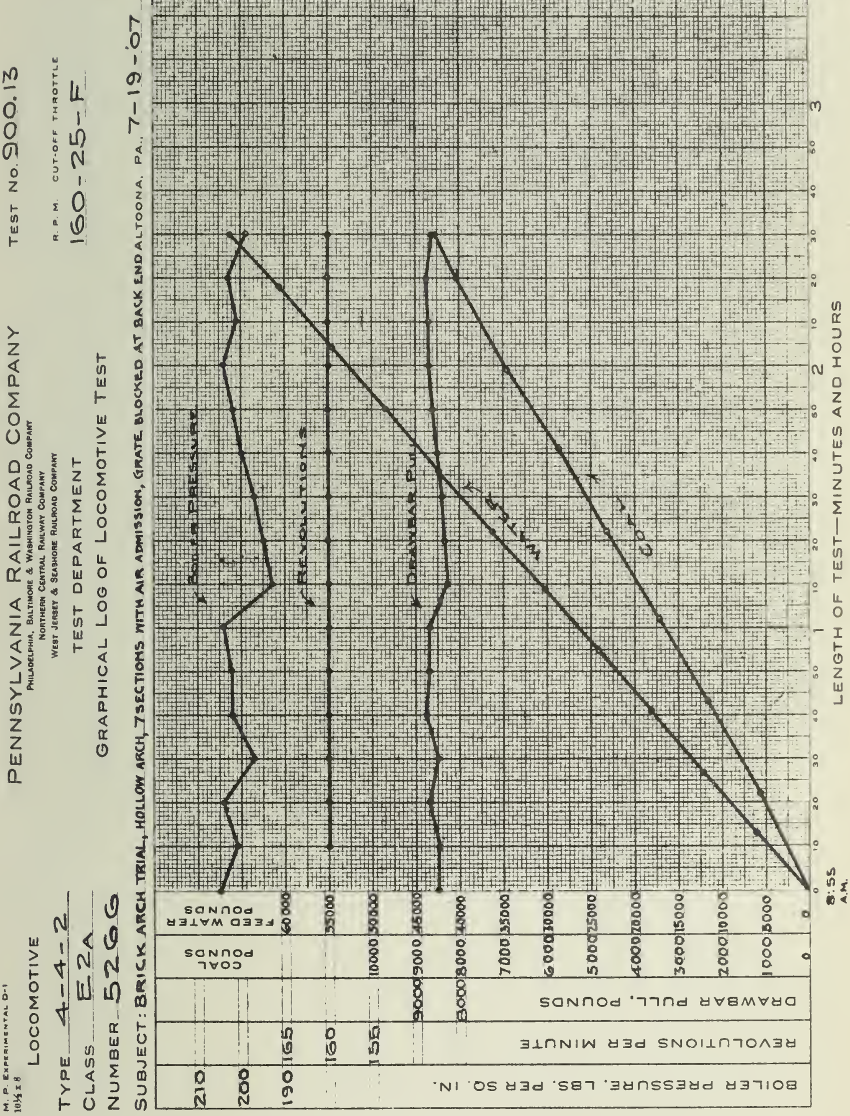
2

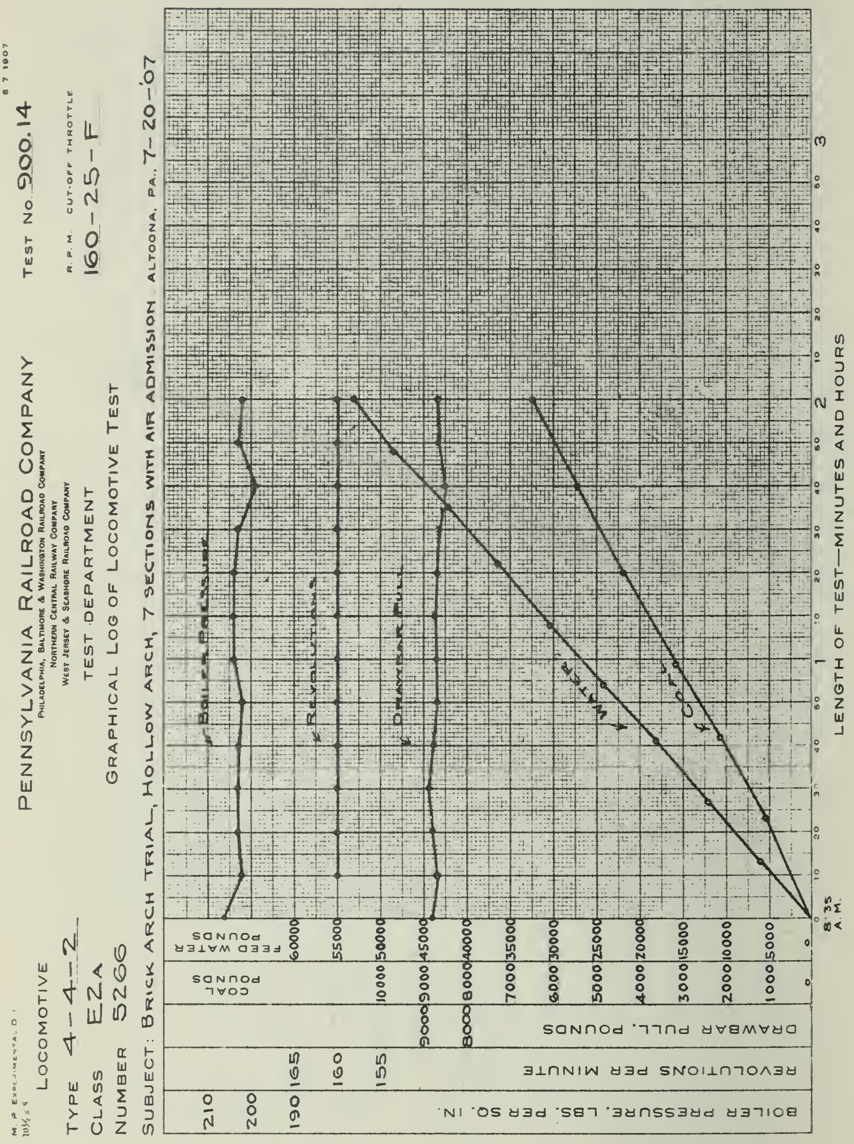
Table 2.
RESULTS OF TESTS WITH AND WITHOUT ARCH.
Tests 900.2, 900.10, 900.11 and 900.17 were made with run of mine coal; the others with screened coal. The tests were from one to two and one-half hours long.


M P Experimental D-1
LOCOMOTIVE
TYPE 4-4-2
CLASS E2A
NUMBER 5266
PENNSYLVANIA RAILROAD COMPANY
PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY
TEST DEPARTMENT
GRAPHICAL LOG OF LOCOMOTIVE TEST
TEST NO 900.10
R.P.M. CUT-OFF THROTTLE
160-25-F
SUBJECT: BRICK ARCH TRIAL, HOLLOW ARCH, 3 SECTIONS LONG WITH AIR ADMISSION. ALTOONA, PA., 7-10-'07
BOILER PRESSURE, LBS. PER SQ. IN.
REVOLUTIONS PER MINUTE
DRAWBAR PULL, POUNDS
COAL POUNDS
FEED WATER POUNDS
BOILER PRESSURE
REVOLUTIONS
DRAWBAR PULL
WATER
COAL
9:0 A.M.
LENGTH OF TEST—MINUTES AND HOURS

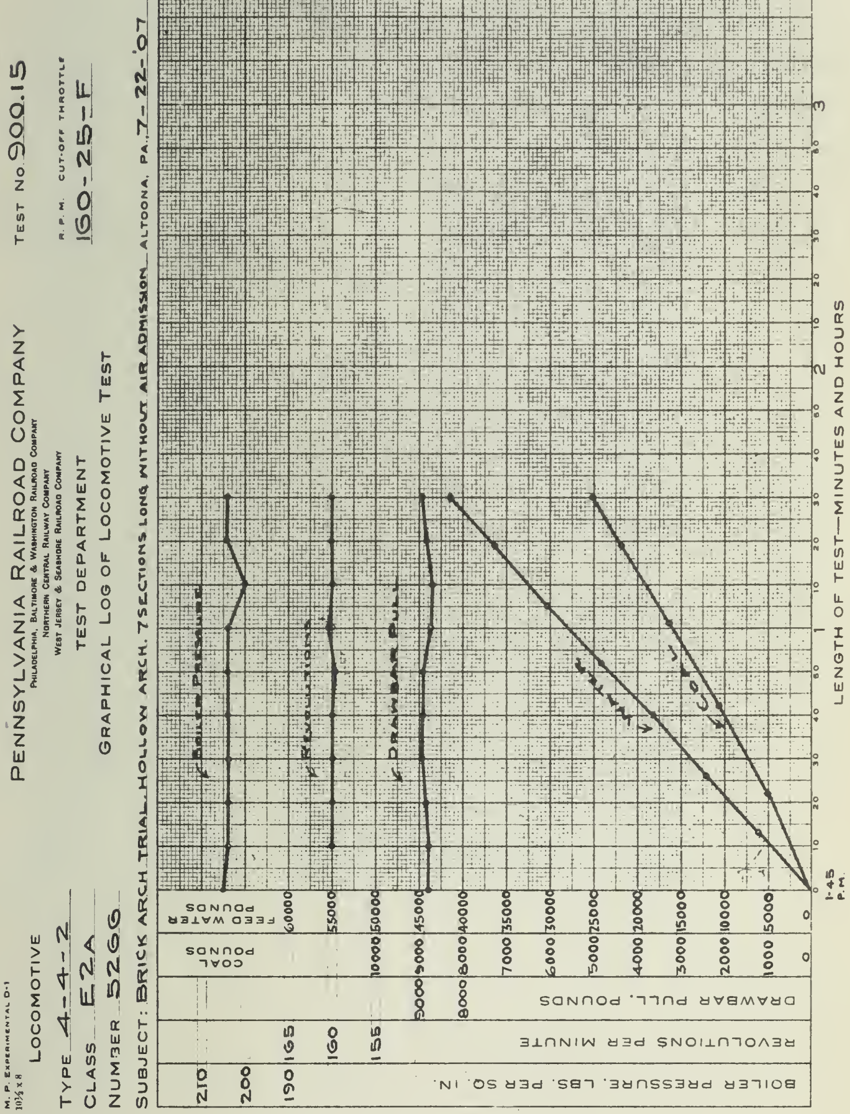

M. P. Experimental O-1
11½ x K
5 7 1907
Pennsylvania Railroad Company
Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company
Test Department
Graphical Log of Locomotive Test
Test No. 900.11
R. P. M. Cut-off Throttle
160-25-F
Locomotive
Type 4-4-2
Class E2A
Number 5266
Subject: Brick Arch Trial, Hollow Arch, 5 Sections with Air Admission
Altoona, Pa., 7-12-'07
Boiler Pressure
Revolutions
Drawbar Pull
Water
Coal
Boiler Pressure, Lbs. per Sq. In.
210
200
190
180
Revolutions per Minute
165
160
155
Drawbar Pull, Pounds
9000
8000
Coal Pounds
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
Feed Water Pounds
60000
55000
50000
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
9:05 A.M.
10
20
30
40
50
1
10
20
30
40
50
2
10
20
30
40
50
3
Length of Test—Minutes and Hours

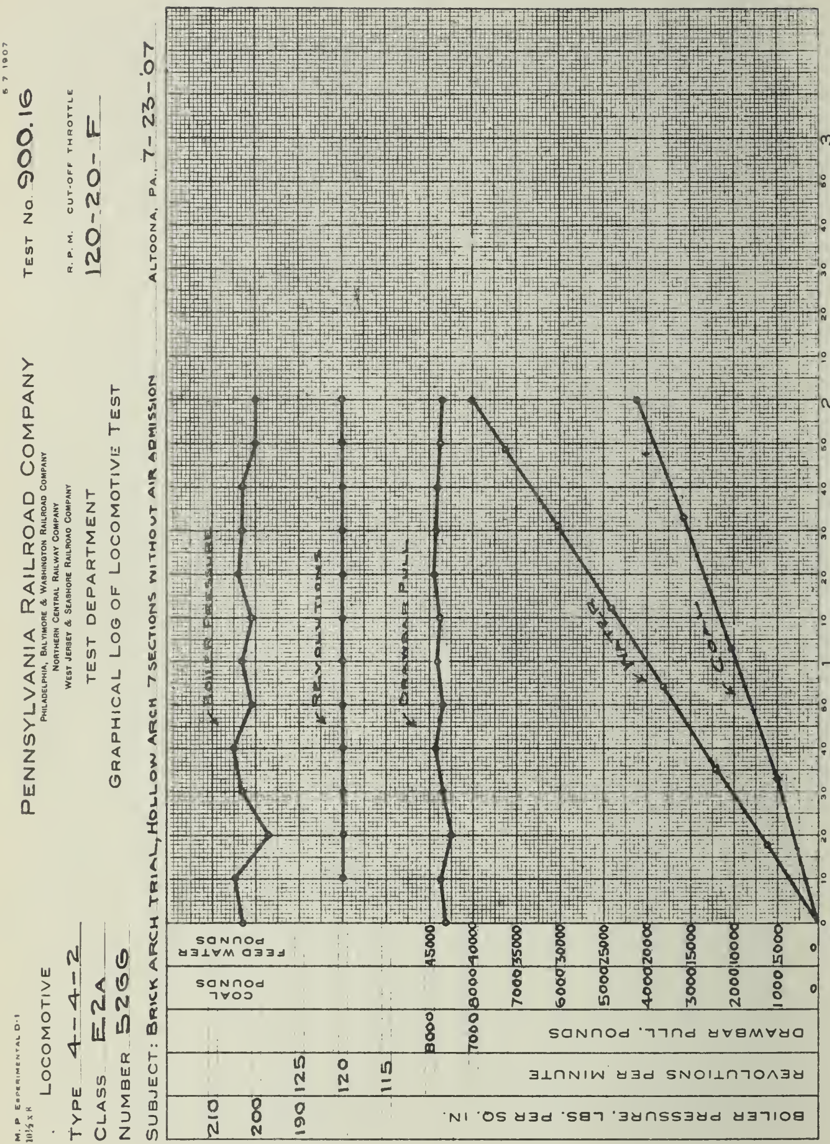

M. P. EXPERIMENTAL D-1
10½ x 8
LOCOMOTIVE
TYPE 4-4-2
CLASS E2A
NUMBER 5266
SUBJECT: BRICK ARCH TRIAL, HOLLOW ARCH, 7 SECTIONS WITH AIR ADMISSION, BACK END OF GRATE BLOCKED
PENNSYLVANIA RAILROAD COMPANY
PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY
TEST DEPARTMENT
GRAPHICAL LOG OF LOCOMOTIVE TEST
TEST NO 900.12
R. P. M. CUT-OFF THROTTLE
160-25-F
ALTOONA, PA. 7-18-'07
BOILER PRESSURE
REVOLUTIONS
DRAWBAR PULL
WATER
COAL
BOILER PRESSURE, LBS. PER SQ. IN.
REVOLUTIONS PER MINUTE
DRAWBAR PULL, POUNDS
COAL POUNDS
FEED WATER POUNDS
9:15 A.M.
LENGTH OF TEST—MINUTES AND HOURS

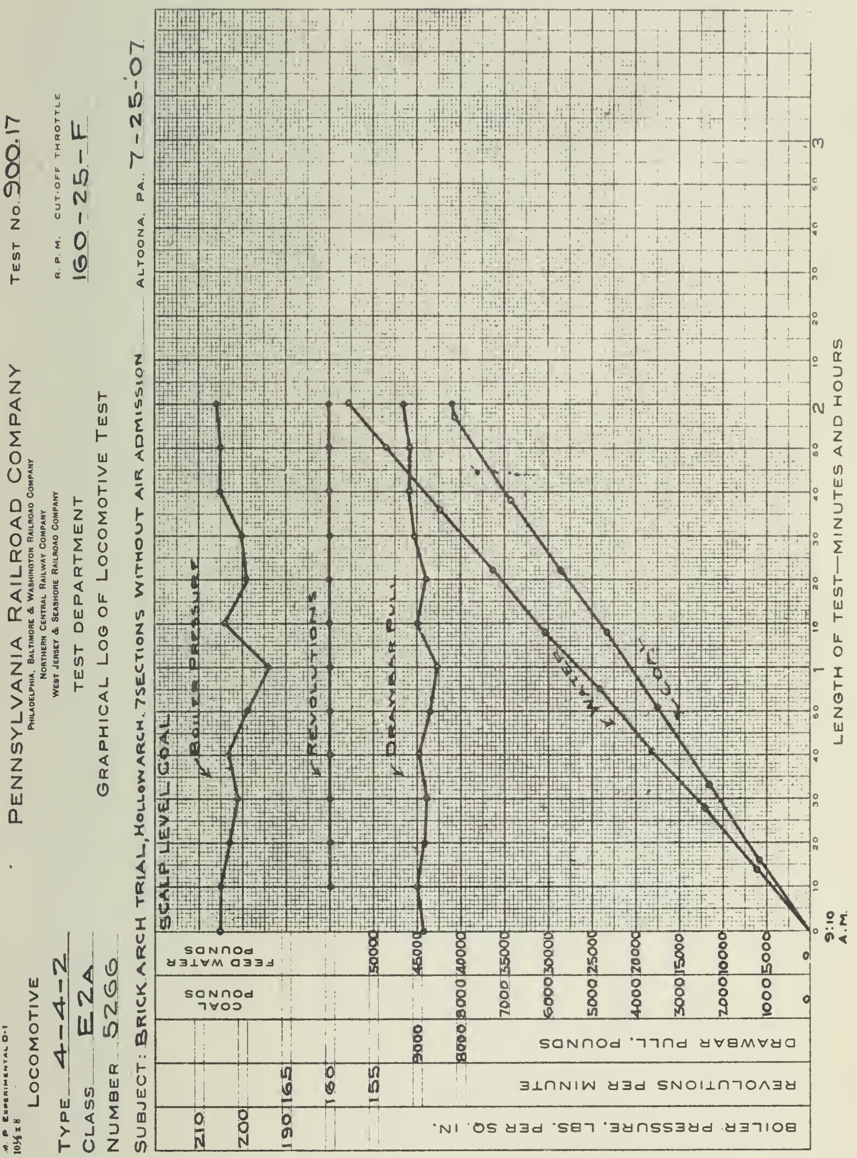

M. P. Experimental D-1
10½ x 8
LOCOMOTIVE
TYPE 4-4-2
CLASS E2A
NUMBER 5266
PENNSYLVANIA RAILROAD COMPANY
Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company
TEST DEPARTMENT
GRAPHICAL LOG OF LOCOMOTIVE TEST
TEST No. 900.13
R. P. M. CUT-OFF THROTTLE
160-25-F
SUBJECT: BRICK ARCH TRIAL, HOLLOW ARCH, 7 SECTIONS WITH AIR ADMISSION, GRATE BLOCKED AT BACK END ALTOONA, PA., 7-19-'07
BOILER PRESSURE, LBS. PER SQ. IN.
REVOLUTIONS PER MINUTE
DRAWBAR PULL, POUNDS
COAL POUNDS
FEED WATER POUNDS
BOILER PRESSURE
REVOLUTIONS
DRAWBAR PULL
WATER
COAL
8:55 A.M.
LENGTH OF TEST—MINUTES AND HOURS



PENNSYLVANIA RAILROAD COMPANY
PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY
TEST DEPARTMENT
GRAPHICAL LOG OF LOCOMOTIVE TEST
LOCOMOTIVE
TYPE 4-4-2
CLASS E2A
NUMBER 5266
TEST NO. 900.14
R.P.M. CUT-OFF THROTTLE
160-25-F
SUBJECT: BRICK ARCH TRIAL, HOLLOW ARCH, 7 SECTIONS WITH AIR ADMISSION ALTOONA, PA., 7-20-'07
BOILER PRESSURE, LBS. PER SQ. IN.
REVOLUTIONS PER MINUTE
DRAWBAR PULL, POUNDS
COAL POUNDS
FEED WATER POUNDS
LENGTH OF TEST—MINUTES AND HOURS
8:35 A.M.
BOILER PRESSURE
REVOLUTIONS
DRAWBAR PULL
WATER
COAL


M. P. Experimental D-1
10½ x 8
Locomotive
Type 4-4-2
Class E2A
Number 5266
Subject: Brick arch trial. Hollow arch. 7 sections long without air admission. Altoona, Pa., 7-22-'07
Pennsylvania Railroad Company
Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company
Test Department
Graphical Log of Locomotive Test
Test No 900.15
R.P.M. Cut-off Throttle
160-25-F
Boiler Pressure
Revolutions
Drawbar Pull
Water
Coal
Boiler pressure, lbs. per sq. in.
Revolutions per minute
Drawbar pull, pounds
Coal pounds
Feed water pounds
1-45 P.M.
Length of test—minutes and hours


M. P. Experimental D-1
PENNSYLVANIA RAILROAD COMPANY
Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company
TEST DEPARTMENT
GRAPHICAL LOG OF LOCOMOTIVE TEST
TEST NO. 900.16
R. P. M. CUT-OFF THROTTLE
120-20-F
LOCOMOTIVE
TYPE 4-4-2
CLASS E2A
NUMBER 5266
SUBJECT: BRICK ARCH TRIAL, HOLLOW ARCH 7 SECTIONS WITHOUT AIR ADMISSION
ALTOONA, PA. 7-23-'07
BOILER PRESSURE
REVOLUTIONS
DRAWBAR PULL
WATER
COAL
BOILER PRESSURE, LBS. PER SQ. IN.
REVOLUTIONS PER MINUTE
DRAWBAR PULL, POUNDS
COAL POUNDS
FEED WATER POUNDS
LENGTH OF TEST—MINUTES AND HOURS
8:45 A.M.



PENNSYLVANIA RAILROAD COMPANY
PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY
TEST DEPARTMENT
GRAPHICAL LOG OF LOCOMOTIVE TEST
LOCOMOTIVE
TYPE 4-4-2
CLASS E2A
NUMBER 5266
TEST NO. 900.17
R.P.M. CUT-OFF THROTTLE
160-25-F
SUBJECT: BRICK ARCH TRIAL, HOLLOW ARCH, 7 SECTIONS WITHOUT AIR ADMISSION
ALTOONA, PA., 7-25-'07
SCALP LEVEL COAL
BOILER PRESSURE
REVOLUTIONS
DRAWBAR PULL
WATER
COAL
BOILER PRESSURE, LBS. PER SQ. IN.
REVOLUTIONS PER MINUTE
DRAWBAR PULL, POUNDS
COAL POUNDS
FEED WATER POUNDS
LENGTH OF TEST—MINUTES AND HOURS
9:10 A.M.

THE H6b CLASS LOCOMOTIVE.
The Type of Locomotive used in the Piston Valve Tests.

PENNSYLVANIA RAILROAD COMPANY

Locomotive Testing Plant

AT

ALTOONA, PENNA.

BULLETIN No. 7 (Revised)

Formerly Bulletin No. 29

PISTON VALVES

1912

LOCOMOTIVE TESTING PLANT.

PISTON VALVES.

(Conclusions and recommendations on pages 6 and 7.)

INTRODUCTION.

1. In the tests of piston valves described in this Bulletin some remarkable results were found in steam leakage with one type of valve. Valves of the Company's own make are found to have very substantial advantages in price over valves of outside manufacturers.

2. Two forms of piston valves are in extended use on our locomotives, one the American Semi-plug, as used on the Lines East, and a valve which will be designated the "L" type, much used on the Lines West. Another form of valve is the Stayman Self-expanding Valve. This Stayman valve is not used on our locomotives.

3. While the three valves differ in details of construction, their overall dimensions were alike so that they would be expected to give practically the same distribution of steam in the cylinder. Differences in service were to be looked for in the amount of steam leakage under various conditions of running.

4. Satisfactory service has been obtained with both the American and "L" type form of valve, and these trials were undertaken, not because of defects found in the valves, but in view of the lower first cost and lower repair costs of the "L" type valves, to determine their performance under identical conditions, where the steam and coal used could be accurately measured.

5. The amount of wear and the expense of maintenance of the valves could not be determined on the Testing Plant. These items could be determined only by wearing out the valves in service.

Description of Valves.

The Stayman Valve.

6. The Stayman Self-expanding Piston Valve is shown in the photographs, Figs. 2 and 3. The valve is made up of a section of four and one-half inch, wrought iron, pipe screwed into castings which carry the packing rings. There is a split cast-iron ring fitting on the valve spindle and outside of this ring there is a heavy cast-iron ring divided into three segments. The segments are held together by brass plates and pins. The ring does not come apart when the valve is removed from the valve cages.

7. The wearing surface of the valve ring is $2\frac{3}{4}$ inches wide and has grooves as shown on the drawing, Fig. 5. Besides the valve stem, the heads of the valve are held together by one through bolt. The valve is 12 inches in diameter, $32\frac{1}{4}$ inches long over the packing rings, is made up of 10 principal parts and weighs 188 pounds.

8. The valve was furnished for test by the Cockburn Barrow & Machine Company of New York, N. Y.

The American Valve.

9. The American Balance Valve Company's Semi-plug valve, as shown in the two photographs with the Stayman valve, is of the same design as the one tested, but is larger in diameter. In the tests, however, the valve used was a 12 inch one. The rings of this valve are shown on the drawing, Fig. 4.

10. The American valve is made up of 17 principal parts and weighs 161 pounds, the heads being held together by two bolts, in addition to the valve stem. The rubbing face of the valve is formed by two narrow expanding or snap rings connected by a thin, wide ring having a number of "V" shaped grooves. Under this wide connecting ring there are wedge-shaped rings as shown in Fig. 4, and from the chamber under the wedge rings there are 18 small ports leading to the live steam side of the valve.

11. This is the standard valve for the "H6b" class of locomotive, and is made by the American Balance Valve Company of Jersey Shore, Pa.

The "L" Type Valve.

12. The "L" type valve is shown on the photographs, Figs. 2 and 3 and on the drawing, Fig. 6. It is made up of a section of

8 inch, outside diameter pipe, riveted to steel castings at the ends. The heads also of the "L" type valves were of steel in the valves tested. There are two "L" shaped cast-iron packing or snap rings with a cast-iron separating ring between them. The separating ring is not divided or split.

13. The packing rings are divided and are held from turning by pins on the lower side of the valve spindle. The heads are held in position by the nut on the valve stem, there being no through bolts as in the other two valves. The valve is 12 inches in diameter, $32\frac{1}{4}$ inches long over the packing rings, is made up of 10 principal parts and weighs $137\frac{1}{2}$ pounds. The valves were furnished by the Pennsylvania Lines, Fort Wayne Shops.

Method of Conducting the Tests.

14. Two different "H6b" locomotives had to be used for these tests; first, No. 2860 for the American and Stayman valves, commencing August 9, 1910, and No. 884 for the "L" type and American valves, commencing September 14, 1911, giving a direct comparison of the American with the other two types. The general arrangement of the "H6b" class locomotive is shown in Fig. 1, and the cylinder and valve in Fig. 7.

American Valve.

15. The American valve, as it was found on the locomotive where it had been in use for over two years, having made about 620 runs of from one-half to three hours duration each, was the first to be tested. The valves, and the cages which had been in service as long as the valves, were then removed, new cages put in and the Stayman valve (new) placed in the new cages and a series of tests made. Following this, American valves were again applied (new) and tested likewise without changing the cages.

"L" Type Valve.

16. New "L" type valves were used and new cages were put in the steam chests. Immediately on starting with the "L" type valves one of them was broken. It was found on removing it from the cage that the openings in the valve rings were passing over open ports in the cages. Both valves were then replaced on the valve stems so that the openings in the rings would travel over one

of the bridges on the lower side of the valve cage and no further difficulty was experienced with the valves after this change.

17. With the American Semi-plug valve no special setting of the valve on the stem is necessary, as the opening in the rings will not catch on the port in any position.

18. After eight tests had been made with the "L" type of valves they were removed and the tests duplicated with the American valves in the same cages. These were repaired valves with new packing rings, making them practically new valves.

19. While data had been obtained for the American valve in the first series of tests, on the other locomotive, it was tried again to make a more accurate comparison with the "L" type valve.

20. Each set of new valves was used in preliminary tests during about one week so that they would be in good running condition and well lubricated before the actual tests were made.

21. The American valve is a very satisfactory one from a mechanical standpoint, while the workmanship on the "L" type valves was not as good from their general appearance, and it is possible that the two types of valves, both carefully made, would show the same results. The valves for tests were not selected with any particular care as it was desired to obtain valves as ordinarily used.

Results of Tests.

22. The Stayman valves show remarkably poor results in steam and coal consumption. In these tests they used from 25 to 200 per cent. more steam, and from 44 to 81 per cent. more coal than the American valves.

23. The speeds ranged from $6\frac{1}{2}$ to $26\frac{1}{2}$ miles per hour, and the cut-offs from 20 to 40 per cent. The results of the tests are shown on the diagrams, Figs. 8 to 11, and on tables 1 to 5.

24. There was a slightly lower coal and steam consumption with the American than with the "L" type valve. The diagrams, Figs. 8 to 11, show curves for the three valves on both locomotives. In Fig. 11, the "L" type valve compared with the American valve shows practically the same results.

25. At the speed of 6.6 miles per hour (40 revolutions per minute) and at a cut-off of about 20 per cent. with the American valves, the drawbar pull was 13,283 pounds, as against a pull of

9,114 pounds with the Stayman valves, under the same conditions as nearly as could be maintained, or a loss by the Stayman valves of 4,159 pounds, equivalent to 31 per cent. of the drawbar pull. At $26\frac{1}{4}$ miles per hour, the highest speed of the tests, a similar comparison of the pulls shows a loss of 3,500 pounds or 29 per cent. with the Stayman valves.

26. The fact that the valves were leaking to such an extent was not evident from the sound of the exhaust while the locomotive was in motion. With the locomotive standing the reverse lever was placed in the centre notch and with the driving wheels on each quarter stroke position the throttle valve was opened. Under these conditions there was a heavy blow or valve leak.

Cost of Valves.

27. The first cost of these valves to equip one locomotive is as follows:

American Semi-plug Piston Valves, complete (2 valves)	$77 00
"L" Type Piston Valves, complete (2 valves)	71 46
Stayman Self-expanding Piston Valves, complete (2 valves)	360 00

28. The cost of renewals of parts most subject to wear, or the rings which are in contact with the valve cages, is as follows:

American Valve (8 snap rings and 4 wide rings)	$15 96
"L" Type Valve (8 snap rings)	3 04
Difference	$12 92
Stayman Valve (4 segment rings)	$180 00

29. The quotations on the Stayman valves are for single valves, while those on the other two are for considerable quantities. The higher price at which the Stayman valve was offered, especially in view of the poor results obtained, made further inquiry as to costs not worth while.

Conclusions.

30. The Stayman piston valves, when in good working order, leak so badly as to seriously limit the hauling power of the locommotive. They used from 25 to 200 per cent. more steam and from 44 to 81 per cent. more coal per unit of power than the standard valves for the "H6b" locomotive.

31. The excessive leakage of this valve is probably due to the rigid construction of the expanding or packing ring. This heavy ring cannot adjust itself to unevenness of the valve cage. This valve is not well adapted to valve cages which are slightly out of alignment at the opposite ends of the steam chest on account of its packing rings being held parallel at all times.

32. The very little difference shown between the "L" type and American valves in steam and coal consumption per unit of power in favor of the American valve, is too small to be given serious consideration (Paragraph 24).

33. There is, on the other hand, a slight advantage in the cost and weight of the complete "L" type over the American valve, and a very large saving possible in the cost of the renewal parts on account of the simplicity of the parts of the "L" type valves (Paragraphs 27, 28 for cost, 10 and 13 for weight).

34. The "L" type of valve may be manufactured without any liability for patent infringement about which there might be some question, in the cases of both the American and Stayman valves.

RECOMMENDATIONS.

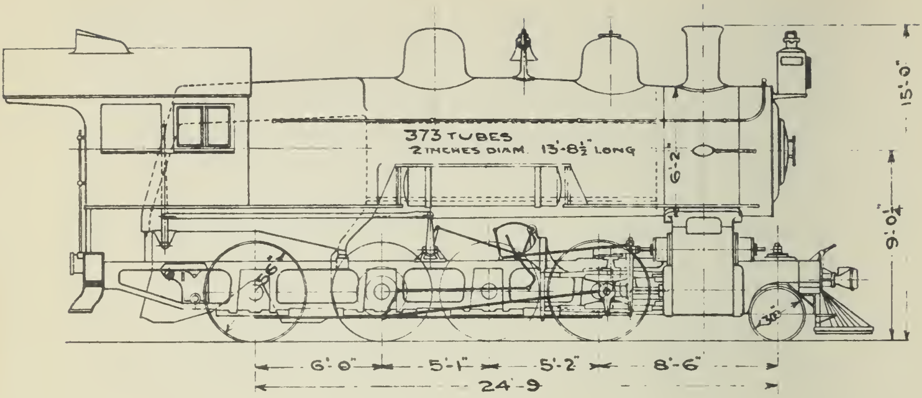
35. The Stayman valve is very wasteful in the consumption of steam and coal and should not be used in any service (Paragraphs 22 and 25).

36. There is pending a complete series of trials to show the leakage of piston valves of sizes ranging from 12 to 18 inches in diameter with various designs of rings. These are to be made on a specially constructed machine. We believe, therefore, in view of the equal performance and of the advantage in maintenance cost of the "L" ring type (Paragraphs 32 and 33) that it should be used for new work and for renewal of American valves when the spool requires replacement.

C. D. YOUNG,
Engineer of Tests.

APPROVED:
J. T. WALLIS,
Genl. Supt. Motive Power.

TEST DEPARTMENT,
ALTOONA, PENNA.,
April 23, 1912.



CLASS H6b LOCOMOTIVE.
The Locomotive used in the Tests.
Fig. 1.

THE LEADING DIMENSIONS OF THE "H6b" LOCOMOTIVE ARE AS FOLLOWS:

Total weight, pounds	198,267
Weight on drivers, pounds	176,600
Cylinders (simple), inches	22x28
Diameter of drivers, inches	56
Fire-box heating surface, square feet	166.4
Heating surface in tubes (water side), square feet	2673.68
Total heating surface (based on water side of tubes), square feet	2839.74
Total heating surface (based on fire side of tubes), square feet	2505.29
Grate area, square feet	48.66
Boiler pressure, pounds	205
Valves	American, Stayman and "L" type
Valve motion	Walschaerts
Fire-box, type	Belpaire
Number of tubes	373
Outside diameter of tubes, inches	2
Length of tubes, inches	164.28

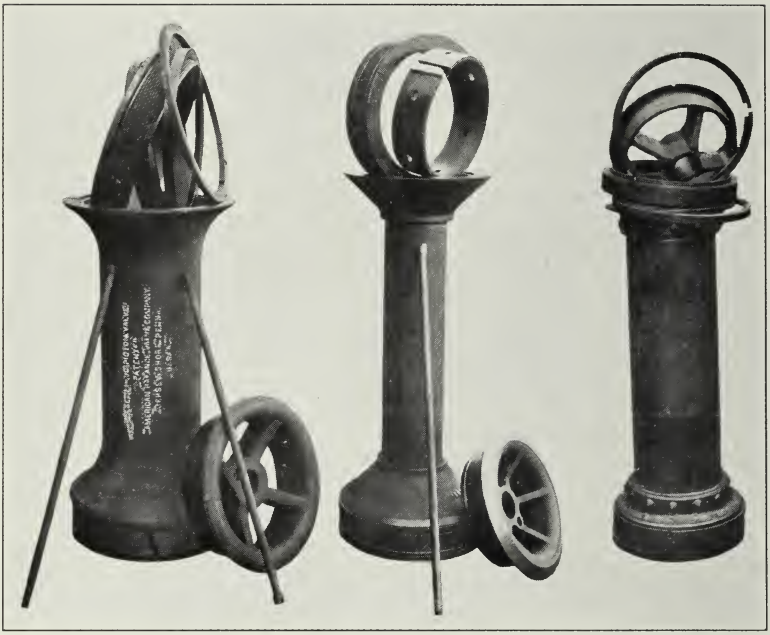
The maximum tractive effort is 39,773 pounds, which is calculated on the assumption that 80 per cent. of the boiler pressure (205 pounds) is available as mean effective pressure at starting.

"L" TYPE VALVE.
Assembled.

AMERICAN VALVE.
Assembled.

STAYMAN VALVE.
Assembled.
12 inch valve.

Fig. 2.

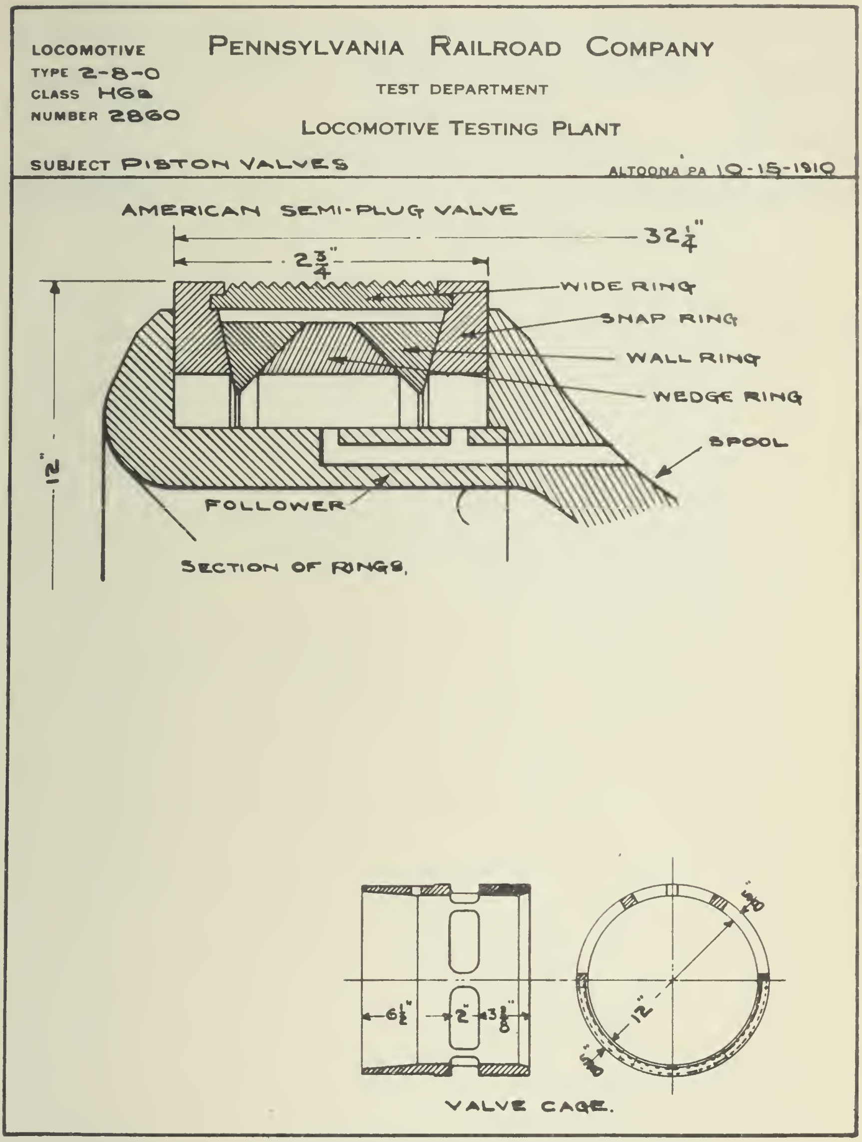


AMERICAN VALVE.
Partly Dismantled.
This is a 14 inch valve of the same general design of the 12 inch valve tested.

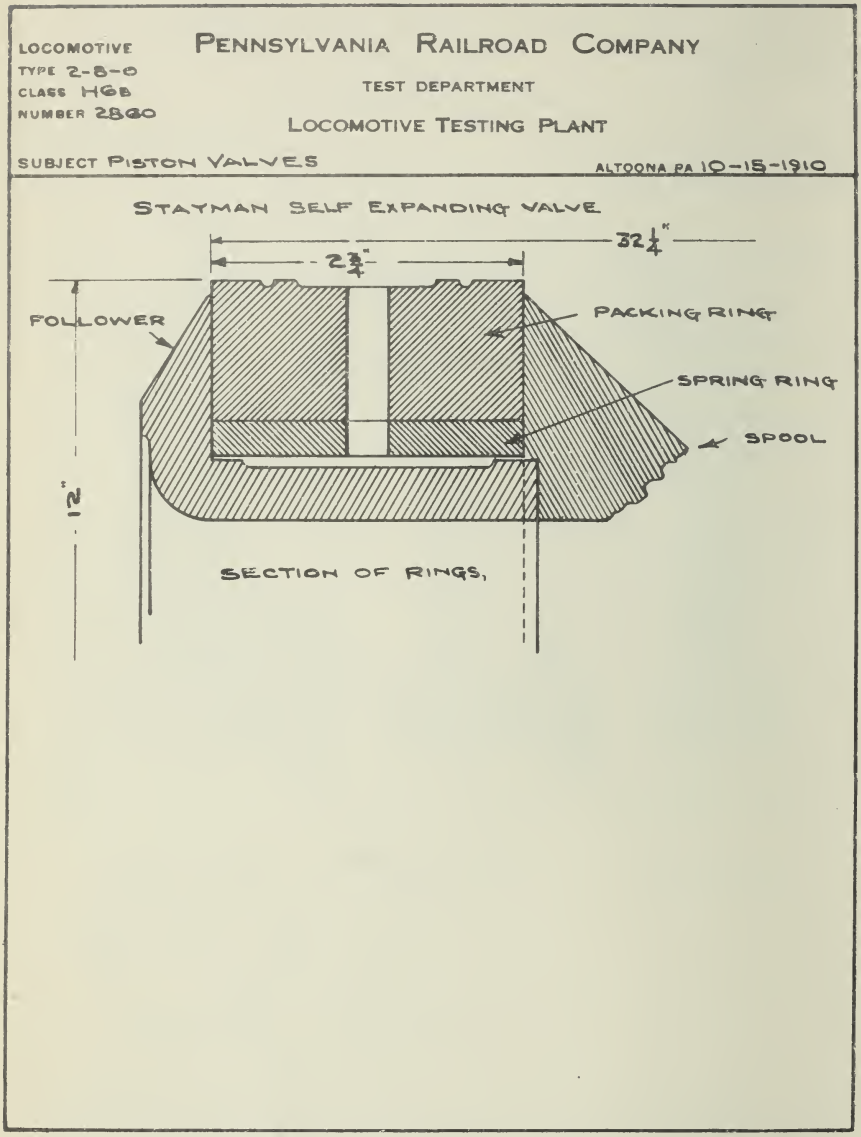
STAYMAN VALVE.
Partly Dismantled.
12 inch valve.

"L" TYPE VALVE.
Partly Dismantled.

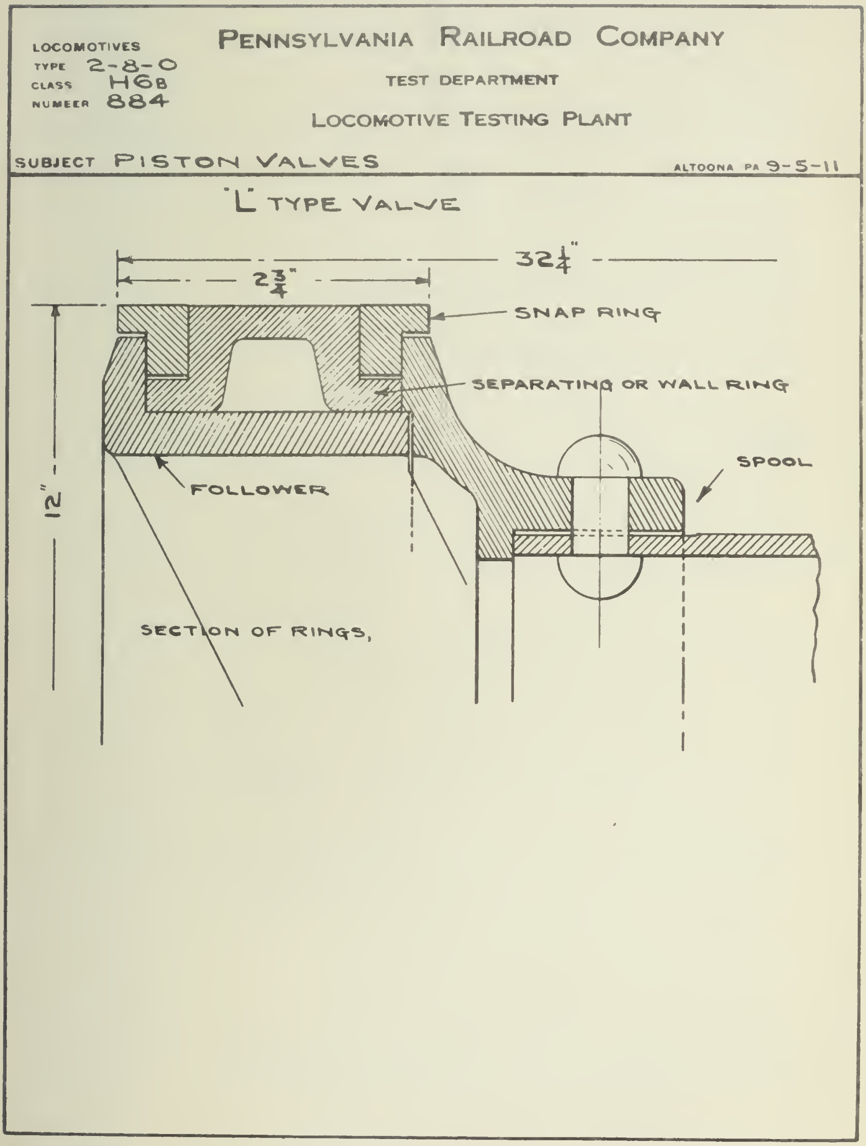
Fig. 3.



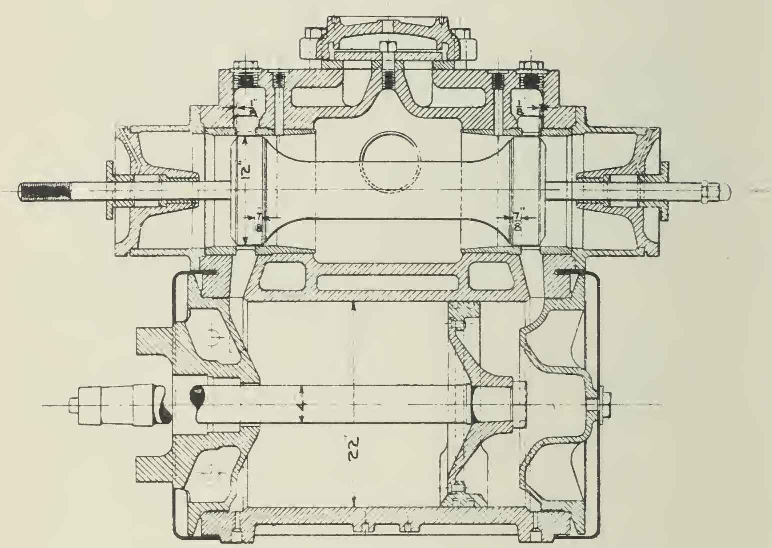
THE AMERICAN SEMI-PLUG PISTON VALVE, SECTION THROUGH THE PACKING RINGS.
There are two packing rings with a wide ring between. Under the wide ring are three wedge rings.
The lower drawing shows the cast-iron cage that is pressed into each end of the steam chest.
Fig. 4.



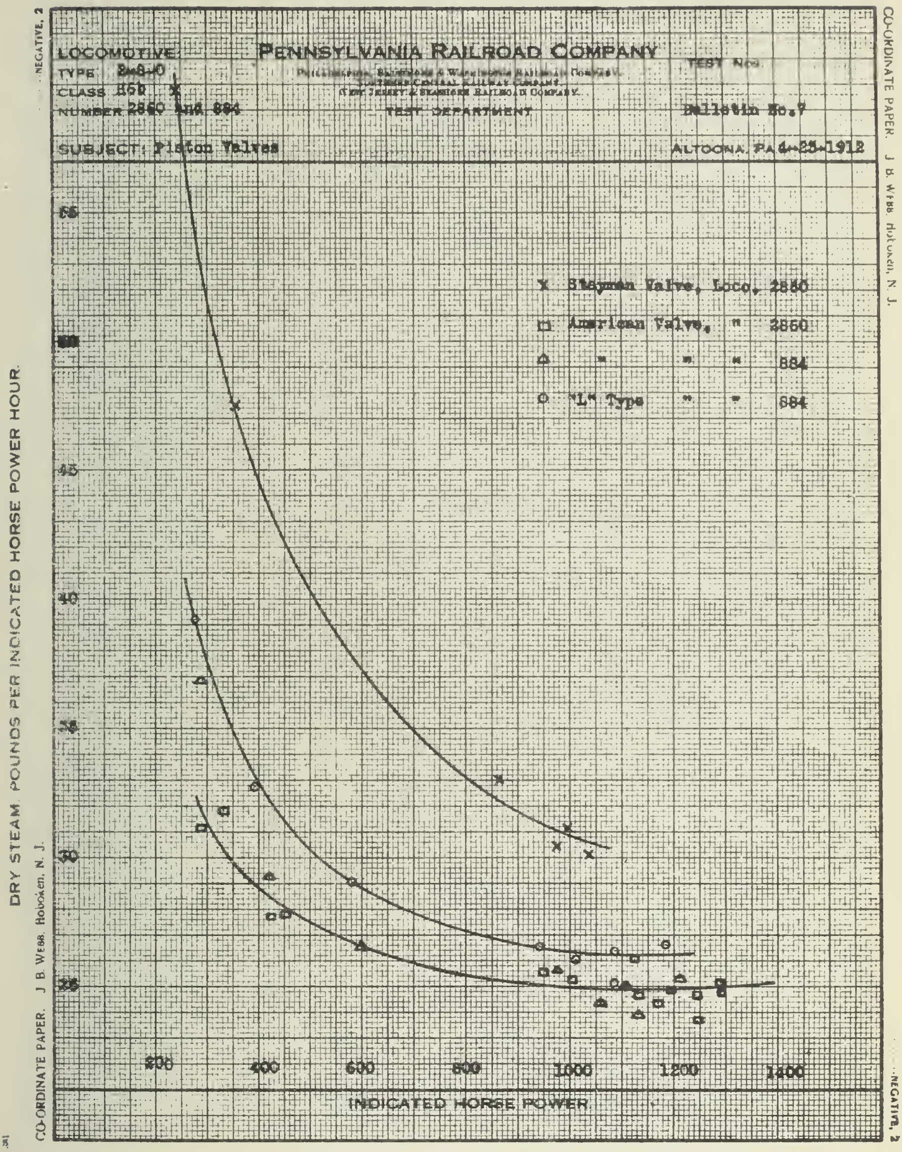
THE STAYMAN SELF-EXPANDING PISTON VALVE, SECTION THROUGH PACKING RINGS.
The packing ring is 1¼ inches thick and 2¾ inches wide. The thin ring under it is the steel expansion or spring ring.
Fig. 5.



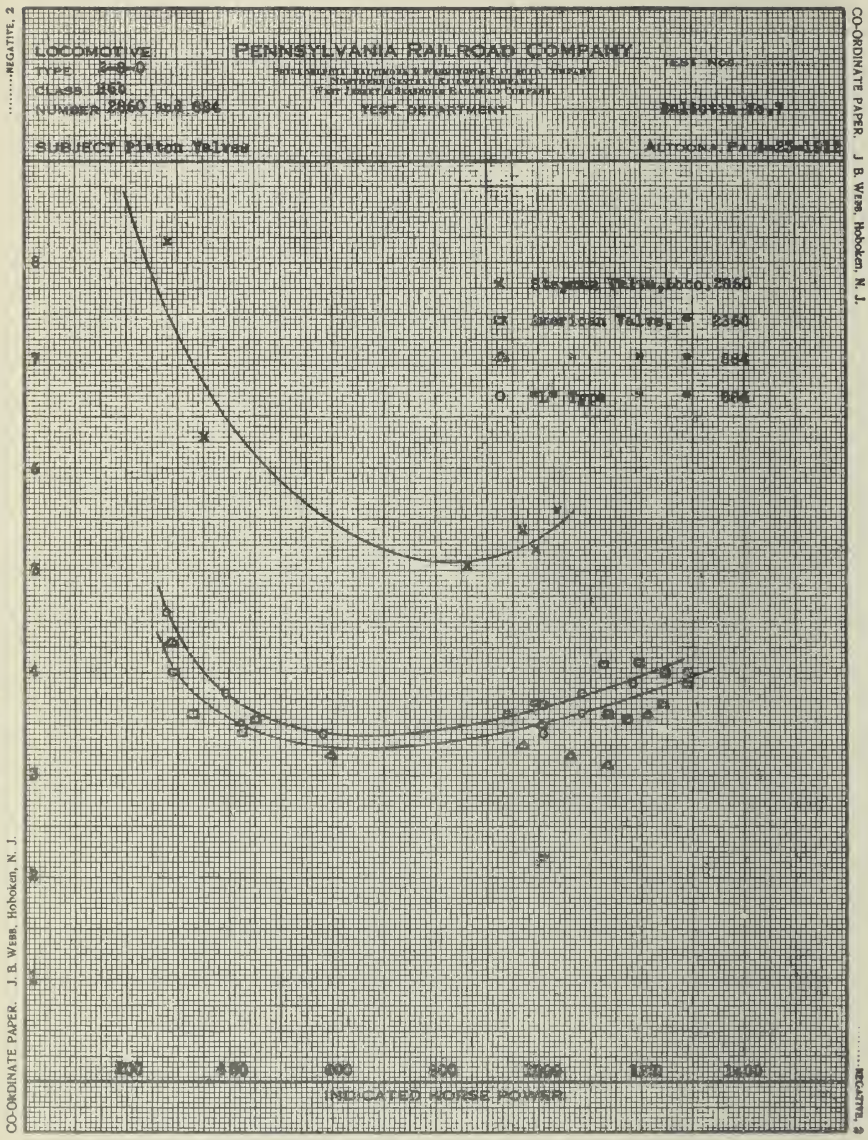
THE "L" TYPE VALVE, SECTION THROUGH RINGS.
The two packing rings are "L" shape in section.
Fig. 6.



SECTION THROUGH CYLINDER AND PISTON VALVE, H6b CLASS LOCOMOTIVE.
The valve has inside admission. The steam lap is $\frac{7}{8}$ inch negative. The exhaust lap is $\frac{1}{8}$ inch negative. Above the valve there is a flat by-pass or drifting valve.
Fig. 7.



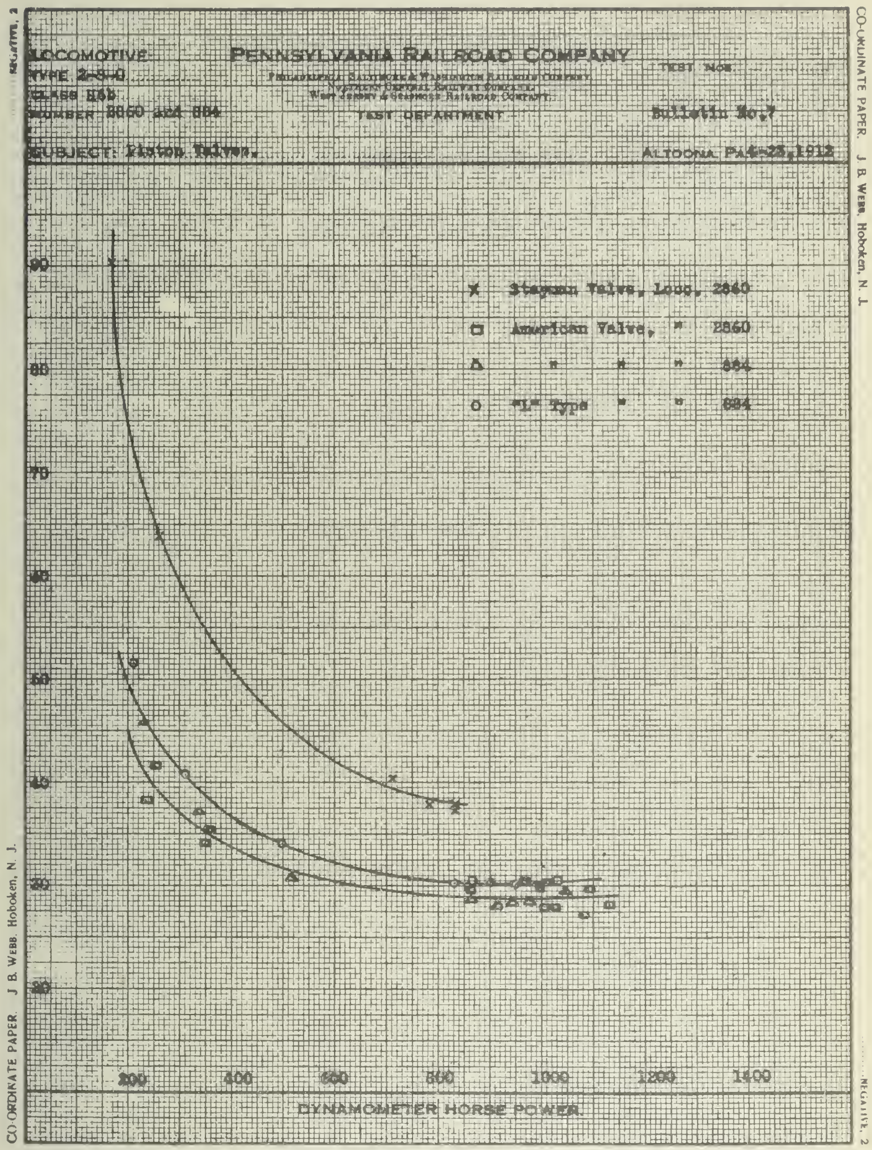
INDICATED HORSEPOWER AND STEAM PER HORSEPOWER FOR THE THREE VALVES.
The Stayman valve shows excessive leakage of steam. The "L" type shows a higher water rate than the American valve.
Fig. 8.



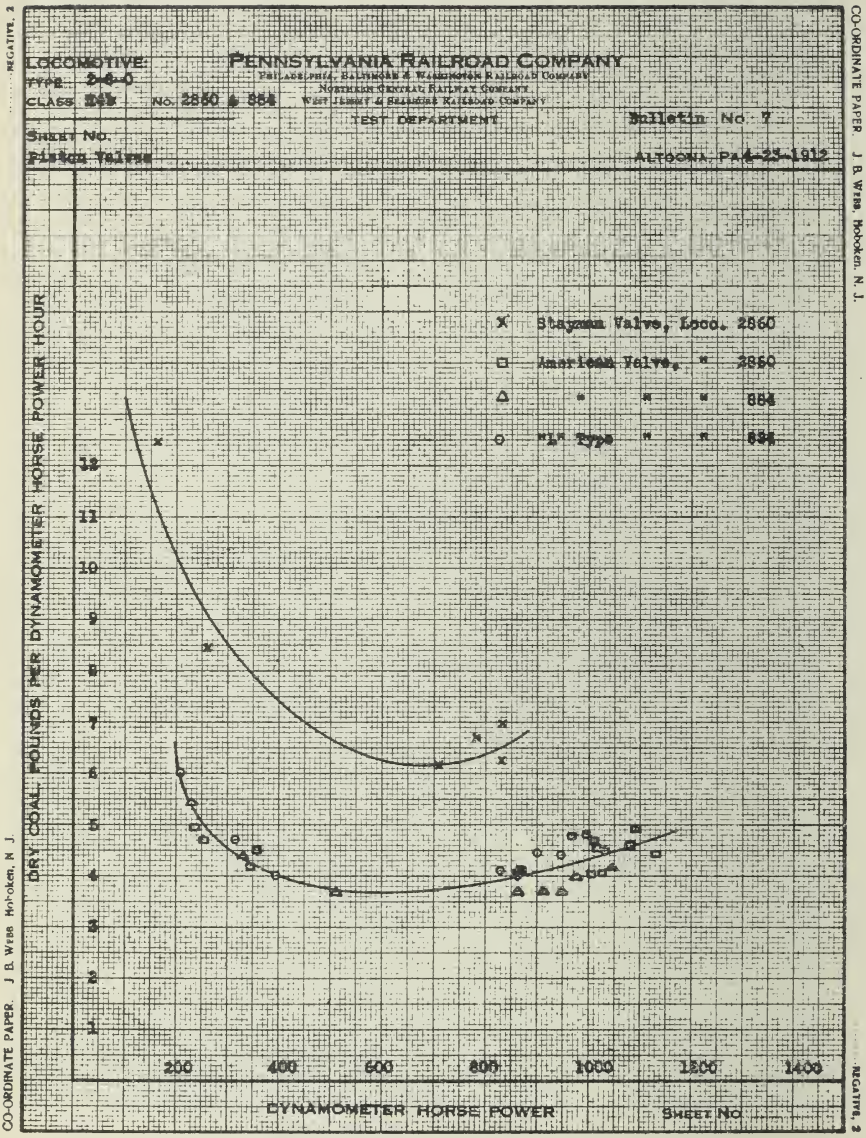
INDICATED HORSEPOWER AND COAL PER HORSEPOWER.

The Stayman valve uses very much more coal than the others per unit of power. The "L" type and American show results practically equal.

Fig. 9.



DYNAMOMETER OR DRAWBAR HORSEPOWER AND STEAM.
The valves show the same characteristics as in Fig. 7.
Fig. 10.



DYNAMOMETER HORSEPOWER AND COAL.

This diagram shows the net power per pound of coal. The Stayman valve uses from 6 to 12.5 pounds per unit of power, while the "L" type and American use from 3.5 to 6 pounds and no difference can be found between them.

Fig. 11.

M. P. 894 A—[illegible] Sheet
8 x 10½

7 6 1907

PENNSYLVANIA RAILROAD COMPANY

Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company

TEST DEPARTMENT

AVERAGE RESULTS OF LOCOMOTIVE TESTS

LOCOMOTIVE:
TYPE 2-8-0
CLASS H8B
NUMBER 2800

FUEL: JAMISON COAL

SUBJECT: PISTON VALVES, AMERICAN SEMI-PLUG   ALTOONA, PA., 10-15-1910

	RUNNING CONDITIONS						BOILER PERFORMANCE				
TEST NUMBER	TEST DESIGNATION	Duration of Test, Hours	Miles per Hour	Throttle Opening, Full or Partial	Actual Cut-off Per Cent., H. P. Cylinders	CONDITION OF VALVES AND CAGES	Pressure in Boiler, Lbs. per Sq. Inch	Draft in Smoke Box, Inches of Water	Draft in Ash Pan, Inches of Water	Calorific Value of Dry Fuel, B.T.U. per Lb.	Cinders Collected in Smoke Box, Pounds per Hour
	S. P. M. Cut-off Throttle	198	199	203	268 to 271		217	222	225	248	238
1200.524	40-20-F	3	6.64	FULL	18.8	OLD	203.8	1.1	0	14186	5
1200.525	60-20-F	3	9.97	"	18.1	"	203.9	1.6	0	"	34
1200.526	80-40-F	2	13.28	"	39.6	"	203.4	4.2	.1	"	53
1200.527	100-40-F	2	16.61	"	40.6	"	204.9	5.1	.1	"	36
1200.528	120-40-F	2	19.94	"	42.1	"	204.4	6.2	.1	"	157
1200.529	140-30-F	2	23.26	"	34.7	"	204.6	5.0	.1	"	76
1200.530	160-30-F	1	26.58	"	32.8	"	204.9	5.4	.1	"	149

	BOILER PERFORMANCE									ENGINE PERFORMANCE	
TEST NUMBER	Dry Fuel Fired per Hour, Pounds	Dry Fuel per Hour, Pounds per Sq. Ft. of Grate	Water Delivered to Boiler, Pounds per Hour	EQUIVALENT EVAPORATION FROM AND AT 212° F., POUNDS: Per Hour	Per Hour per Sq. Ft. of Fire Heating Sur.	Per Pound of Dry Fuel	Boiler Horse Power (34½ U. of E.)	Efficiency of Boiler, Based on Fuel		Pressure in Branch Pipe, Pounds per Sq. In.	Superheat in Branch Pipe, Degrees F.
	338	339	340	344	345	347	349	350		220	230
1200.524	1163	23.90	9640	11405	4.55	9.81	330.6	66.79			
1200.525	1452	29.84	11900	14079	5.62	9.70	408.1	66.04			
1200.526	3505	72.03	24669	29340	11.71	8.37	850.4	56.98			
1200.527	4086	83.97	28391	33825	13.50	8.28	980.4	56.37			
1200.528	5004	102.84	32384	38589	15.40	7.71	1118.5	52.49			
1200.529	4148	85.25	28853	34362	13.72	8.28	996.0	56.37			
1200.530	4964	102.02	29770	35477	14.16	7.15	1028.3	48.68			

	ENGINE PERFORMANCE					LOCOMOTIVE PERFORMANCE						
TEST NUMBER	Dry Steam to Engines, Pounds per Hour	Indicated Horse Power	Dry Fuel per Indicated Horse Power Hour, Pounds	Dry Steam per Indicated Horse Power Hour, Pounds		Drawbar Pull, Pounds	Dynamometer or Drawbar Horse Power	Dry Fuel per Dynamom. Horse Power Hour, Pounds	Dry Steam per Dynamom. Horse Power Hour, Pounds	Machine Efficiency of Locomotive, Per Cent.	Thermal Efficiency of Locomotive, per Cent., (Based on Fuel)	
	214	379	380	381		265	383	384	385	398	399	
1200.524	9014	289.4	4.02	31.15		13273	235.2	4.94	38.32	81.3	3.6	
1200.525	11756	423.7	3.43	27.75		13026	346.2	4.19	33.96	81.7	4.3	
1200.526	24215	947.4	3.70	25.56		24358	863.2	4.06	28.05	91.1	4.4	
1200.527	28047	1133.2	3.61	24.75		22669	1004.2	4.07	27.93	88.6	4.4	
1200.528	31942	1288.3	3.88	24.79		21303	1132.5	4.42	28.20	87.9	4.1	
1200.529	28504	1170.3	3.54	24.36		16489	1022.6	4.06	27.87	87.4	4.4	
1200.530	29410	1244.2	3.99	23.64		15269	1082.3	4.59	27.17	87.0	3.9	

RESULTS OF TESTS WITH AMERICAN VALVES, OLD VALVES AND CAGES.
Table 1.

M. P. 304 A—Sixth Sheet
8 x 10½

7 6 1907

PENNSYLVANIA RAILROAD COMPANY

Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company

TEST DEPARTMENT

AVERAGE RESULTS OF LOCOMOTIVE TESTS

LOCOMOTIVE:
TYPE 2-8-0
CLASS H6B
NUMBER 2860

FUEL: JAMISON COAL

SUBJECT: PISTON VALVES, STAYMAN

ALTOONA, PA., 10-15-1910

	RUNNING CONDITIONS						BOILER PERFORMANCE				
TEST NUMBER	TEST DESIGNATION	Duration of Test, Hours	Miles per Hour	Throttle Opening, Full or Partial	Actual Cut-off Per Cent., H. P. Cylinders	Condition of Valves and Cages	Pressure in Boiler, Lbs. per Sq. Inch	Draft in Smoke Box, Inches of Water	Draft in Ash Pan, Inches of Water	Calorific Value of Dry Fuel, B.T.U. per Lb.	Cinders Collected in Smoke Box, Pounds per Hour
	R. P. M. Cut-off Throttle	196	199	203	268 to 271		217	222	225	248	238
1200.556	40-20-F.	3	6.62	Full	18.7	New	204.5	2.2	0	13547	26
1200.557	60-20-F	3	9.93	"	19.1	"	203.6	2.4	0	-	27
1200.554	80-40-F	2	13.24	"	37.5	"	202.6	5.4	.1	-	112
1200.555	100-40-F	2	16.55	"	39.0	"	201.6	6.4	.1	-	193
				"						-	
1200.558	140-30-F	1.25	23.16	"	30.0	"	202.9	5.9	.1	-	277
1200.559	160-30-F	1	26.47	"	28.4	"	202.1	5.9	.1	-	428

	BOILER PERFORMANCE									ENGINE PERFORMANCE	
TEST NUMBER	Dry Fuel Fired per Hour, Pounds	Dry Fuel per Hour, Pounds per Sq. Ft. of Grate	Water Delivered to Boiler, Pounds per Hour	Equivalent Evaporation from and at 212° F., Pounds: Per Hour	Per Hour per Sq. Ft. of Fire Heating Sur.	Per Pound of Dry Fuel	Boiler Horse Power (34½ U. of E.)	Efficiency of Boiler, Based on Fuel		Pressure in Branch Pipe, Pounds per Sq. In.	Superheat in Branch Pipe, Degrees F.
	338	339	340	344	345	347	349	350		220	230
1200.556	2002	41.14	15796	18777	7.50	9.38	544.3	66.87			
1200.557	2212	45.48	17433	20704	8.26	9.36	600.1	66.73			
1200.554	4384	90.10	28993	34617	13.82	7.90	1003.4	56.32			
1200.555	5186	106.58	31936	38116	15.21	7.35	1104.8	52.40			
1200.558	5239	107.67	30288	36188	14.44	6.91	1048.9	49.26			
1200.559	5781	118.81	31804	37982	15.16	6.57	1100.9	46.84			

	ENGINE PERFORMANCE					LOCOMOTIVE PERFORMANCE						
TEST NUMBER	Dry Steam to Engines, Pounds per Hour	Indicated Horse Power	Dry Fuel per Indicated Horse Power Hour, Pounds	Dry Steam per Indicated Horse Power Hour, Pounds		Drawbar Pull, Pounds	Dynamometer or Drawbar Horse Power	Dry Fuel per Dynamom. Horse Power Hour, Pounds	Dry Steam per Dynamom. Horse Power Hour, Pounds	Machine Efficiency of Locomotive, Per Cent.	Thermal Efficiency of Locomotive, per Cent., (Based on Fuel)	
	214	379	380	381		265	383	384	385	398	399	
1200.556	14566	243.4	8.23	59.84		9114	160.8	12.45	90.58	66.1	1.51	
1200.557	16694	351.4	6.30	47.51		9863	261.1	8.47	63.94	74.3	2.28	
1200.554	28478	862.6	5.04	33.01		20084	708.9	6.18	40.17	81.2	3.04	
1200.555	31152	995.8	5.21	31.28		18852	831.8	6.23	37.45	83.5	3.02	
1200.558	29668	971.1	5.39	30.55		12670	782.6	6.69	37.91	80.6	2.81	
1200.559	31238	1036.5	5.58	30.14		11758	830.0	6.97	37.64	80.1	2.70	

RESULTS OF TESTS WITH STAYMAN VALVES, NEW VALVES AND CAGES.
Table 2.

M. P. 394 A—Sixth Sheet
8 x 10½

7 6 1907

PENNSYLVANIA RAILROAD COMPANY

Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company

TEST DEPARTMENT

AVERAGE RESULTS OF LOCOMOTIVE TESTS

LOCOMOTIVE:
TYPE 2-8-0
CLASS H6B
NUMBER 2860

FUEL: JAMISON COAL

SUBJECT: PISTON VALVES, AMERICAN SEMI-PLUG ALTOONA, PA., 10-15-1910

TEST NUMBER	RUNNING CONDITIONS						BOILER PERFORMANCE				
	TEST DESIGNATION	Duration of Test, Hours	Miles per Hour	Throttle Opening, Full or Partial	Actual Cut-off Per Cent., H. P. Cylinders	CONDITION OF VALVES AND CAGES	Pressure in Boiler, Lbs. per Sq. Inch	Draft in Smoke Box, Inches of Water	Draft in Ash Pan, Inches of Water	Calorific Value of Dry Fuel, B.T.U. per Lb.	Cinders Collected in Smoke Box, Pounds per Hour
	R. P. M. Cut-off Throttle	196	199	203	268 to 271		217	222	225	248	238
1200.571	40-20-F.	3	6.62	FULL	22.5	NEW	205.2	1.3	0	13766	42
1200.572	60-20-F	3	9.93	"	21.2	"	204.9	1.6	0	"	23
1200.573	80-40-F	2	13.24	"	40.9	"	204.8	4.4	.1	"	59
1200.574	100-40-F	2	16.55	"	42.3	"	201.2	5.4	.1	"	181
1200.575	120-40-F	1.5	19.85	"	41.7	"	203.9	6.2	.1	"	147
1200.576	140-30-F	2	23.16	"	35.5	"	202.5	5.4	0	"	172
1200.577	160-30-F	1	26.47	"	32.1	"	205.0	5.7	.1	"	193

TEST NUMBER	BOILER PERFORMANCE									ENGINE PERFORMANCE	
	Dry Fuel Fired per Hour, Pounds	Dry Fuel per Hour, Pounds per Sq. Ft. of Grate	Water Delivered to Boiler, Pounds per Hour	EQUIVALENT EVAPORATION FROM AND AT 212° F., POUNDS: Per Hour	Per Hour per Sq. Ft. of Fire Heating Sur.	Per Pound of Dry Fuel	Boiler Horse Power (34½ U. of E.)	Efficiency of Boiler, Based on Fuel		Pressure in Branch Pipe, Pounds per Sq. In.	Superheat in Branch Pipe, Degrees F.
	338	339	340	344	345	347	349	350		220	230
1200.571	1188	24.41	10966	13008	5.19	10.95	377.0	76.82			
1200.572	1597	32.82	13213	15679	6.26	9.82	454.5	68.90			
1200.573	3536	72.67	25738	30779	12.29	8.70	892.2	61.04			
1200.574	4612	94.78	29875	35662	14.23	7.73	1034.0	54.23			
1200.575	5359	110.13	32875	39287	15.68	7.33	1138.8	51.43			
1200.576	4791	98.46	30150	36064	14.40	7.53	1045.4	52.83			
1200.577	4623	95.01	31154	37240	14.86	8.06	1079.4	56.55			

TEST NUMBER	ENGINE PERFORMANCE					LOCOMOTIVE PERFORMANCE					
	Dry Steam to Engines, Pounds per Hour	Indicated Horse Power	Dry Fuel per Indicated Horse Power Hour, Pounds	Dry Steam per Indicated Horse Power Hour, Pounds		Drawbar Pull, Pounds	Dynamometer or Drawbar Horse Power	Dry Fuel per Dynamom. Horse Power Hour, Pounds	Dry Steam per Dynamom. Horse Power Hour, Pounds	Machine Efficiency of Locomotive, Per Cent.	Thermal Efficiency of Locomotive, per Cent., Based on Fuel
	214	379	380	381		265	383	384	385	398	399
1200.571	10491	329.5	3.61	31.84		14302	252.4	4.71	41.56	76.6	3.93
1200.572	12524	450.1	3.55	27.82		13392	354.5	4.50	35.33	78.8	4.11
1200.573	25343	1003.4	3.52	25.26		24385	860.5	4.11	29.45	85.8	4.50
1200.574	29323	1126.5	4.09	26.03		21898	966.1	4.77	30.35	85.8	3.88
1200.575	32477	1289.3	4.16	25.19		20642	1092.9	4.90	29.72	84.8	3.77
1200.576	29651	1195.0	4.01	24.81		16106	994.8	4.82	29.81	83.2	3.84
1200.577	30568	1242.2	3.72	24.61		14342	1012.4	4.57	30.19	81.5	4.05

RESULTS OF TESTS WITH AMERICAN VALVES, NEW VALVES AND CAGES.
Table 3.

M. P. 394 A—Sixth Sheet
8 x 10½

11-9-10

PENNSYLVANIA RAILROAD COMPANY

Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company

TEST DEPARTMENT

AVERAGE RESULTS OF LOCOMOTIVE TESTS

LOCOMOTIVE:
TYPE 2-8-0
CLASS H6B
NUMBER 884

FUEL: JAMISON COAL

SUBJECT: PISTON VALVES, "L" TYPE

ALTOONA, PA., 10-18-1911

TEST NUMBER	RUNNING CONDITIONS: Test Designation	Duration of Test, Hours	Miles per Hour	Throttle Opening, Full or Partial	Actual Cut-off Per Cent., H. P. Cylinders		BOILER PERFORMANCE: Pressure in Boiler, Lbs. per Sq. Inch	Draft in Smoke Box, Inches of Water	Draft in Ash Pan, Inches of Water	Calorific Value of Dry Fuel, B. T. U. per Lb.	Cinders Collected in Smoke Box, Pounds per Hour
	R. P. M. Cut-off Throttle	196	199	203	268 to 271		217	222	225	248	238
2201	40-20-F	3	6.6	FULL	18.2		206.4	1.1	0	14023	5
2202	60-20-F	3	9.9	"	18.2		206.0	1.4	0	"	7
2203	60-30-F	2.5	9.9	"	28.9		206.8	2.2	0	"	17
2204	80-40-F	2	13.2	"	39.2		205.5	4.3	0	"	37
2205	100-40-F	2	16.5	"	41.1		204.8	5.2	0	"	48
2206	120-40-F	2	19.8	"	40.9		205.8	6.0	0	"	114
2207	140-30-F	2	23.1	"	30.5		206.0	4.8	0	"	57
2208	160-30-F	2	26.4	"	30.0		205.6	4.9	0	"	62

TEST NUMBER	BOILER PERFORMANCE: Dry Fuel Fired per Hour, Pounds	Dry Fuel per Hour, Pounds per Sq. Ft. of Grate	Water Delivered to Boiler, Pounds per Hour	Equivalent Evaporation from and at 212° F., Pounds: Per Hour	Per Hour per Sq. Ft. of Fire Heating Sur.	Per Pound of Dry Fuel	Boiler Horse Power (34½ U. of E.)	Efficiency of Boiler, Based on Fuel		ENGINE PERFORMANCE: Pressure in Branch Pipe, Pounds per Sq. In.	Superheat in Branch Pipe, Degrees F.
	338	339	340	344	345	347	349	350		220	230
2201	1284	25.6	11520	13679	5.4	10.7	396.5	73.7			
2202	1496	29.8	12972	15389	6.1	10.3	446.1	71.2			
2203	1966	39.1	17195	20558	8.2	10.5	595.9	72.3			
2204	3387	67.4	25011	30091	12.0	8.9	872.2	61.4			
2205	4152	82.7	28792	34504	13.7	8.3	1000.1	57.5			
2206	4653	92.6	31628	37954	15.1	8.2	1100.1	56.4			
2207	3467	69.0	26373	31703	12.6	9.1	918.9	63.2			
2208	3931	78.3	27379	32994	13.1	8.4	956.4	58.0			

TEST NUMBER	ENGINE PERFORMANCE: Dry Steam to Engines, Pounds per Hour	Indicated Horse Power	Dry Fuel per Indicated Horse Power Hour, Pounds	Dry Steam per Indicated Horse Power Hour, Pounds		LOCOMOTIVE PERFORMANCE: Drawbar Pull, Pounds	Dynamometer or Drawbar Horse Power	Dry Fuel per Dynamom. Horse Power Hour, Pounds	Dry Steam per Dynamom. Horse Power Hour, Pounds	Machine Efficiency of Locomotive, Per Cent.	Thermal Efficiency of Locomotive, per Cent. (Based on Fuel)	
	214	379	380	381		265	383	384	385	398	399	
2201	10958	279.2	4.6	39.3		12070	212.6	6.0	51.5	76.1	3.0	
2202	12873	394.3	3.8	32.7		11938	315.4	4.7	40.8	80.0	3.8	
2203	16904	581.0	3.4	29.1		18840	497.7	4.0	34.0	85.7	4.6	
2204	24990	943.9	3.6	26.5		23570	830.2	4.1	30.1	88.0	4.5	
2205	28716	1086.5	3.8	26.4		21565	949.5	4.4	30.2	87.4	4.2	
2206	31583	1185.4	3.9	26.6		19519	1031.3	4.5	30.6	87.0	4.0	
2207	26301	1012.7	3.4	26.0		14005	863.3	4.0	30.5	85.2	4.5	
2208	27332	1086.0	3.6	25.2		12803	901.9	4.4	30.3	83.0	4.2	

RESULTS OF TESTS WITH "L" TYPE VALVES ON LOCOMOTIVE 884.
Table 4.

M. P. 884 A—Sixth Sheet
8 x 10½

11-9-10

PENNSYLVANIA RAILROAD COMPANY

Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company

TEST DEPARTMENT

LOCOMOTIVE:
TYPE 2-8-0
CLASS H6B
NUMBER 884

FUEL: JAMISON COAL

AVERAGE RESULTS OF LOCOMOTIVE TESTS

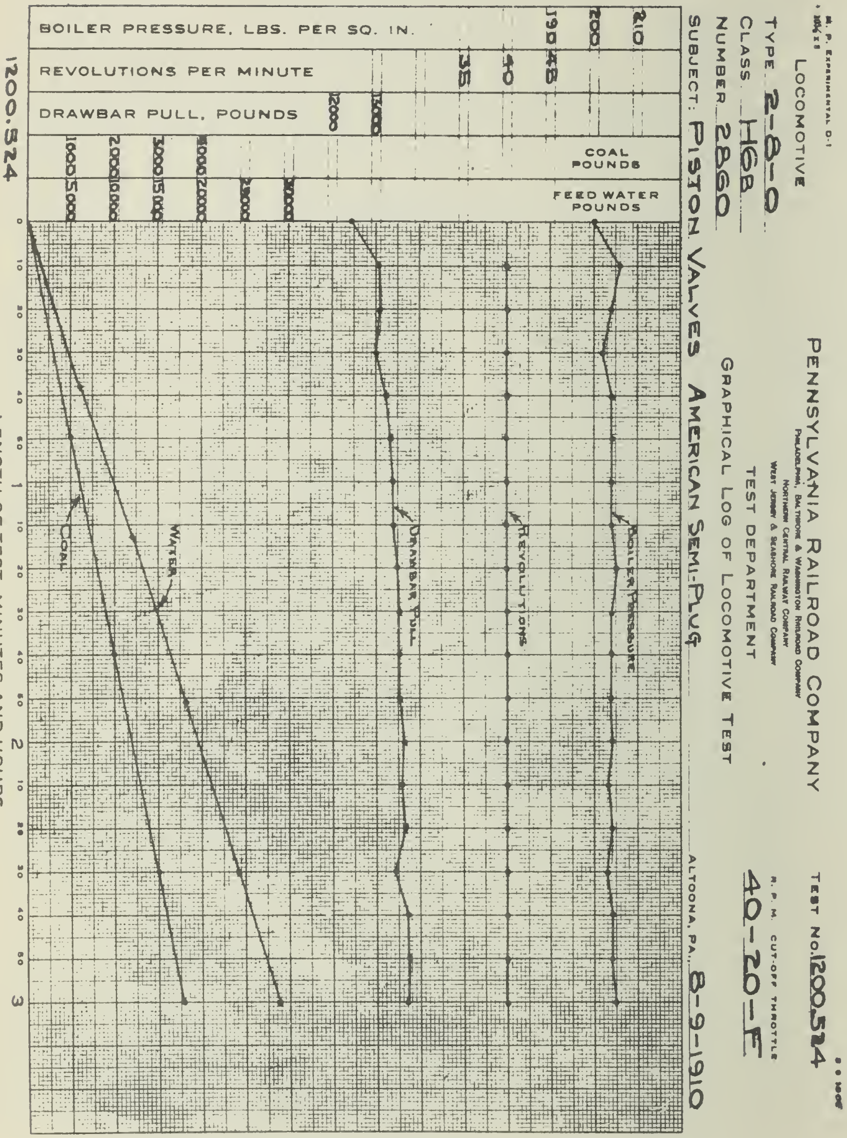
SUBJECT: PISTON VALVES, AMERICAN SEMI PLUG ALTOONA, PA., 10-18-1911

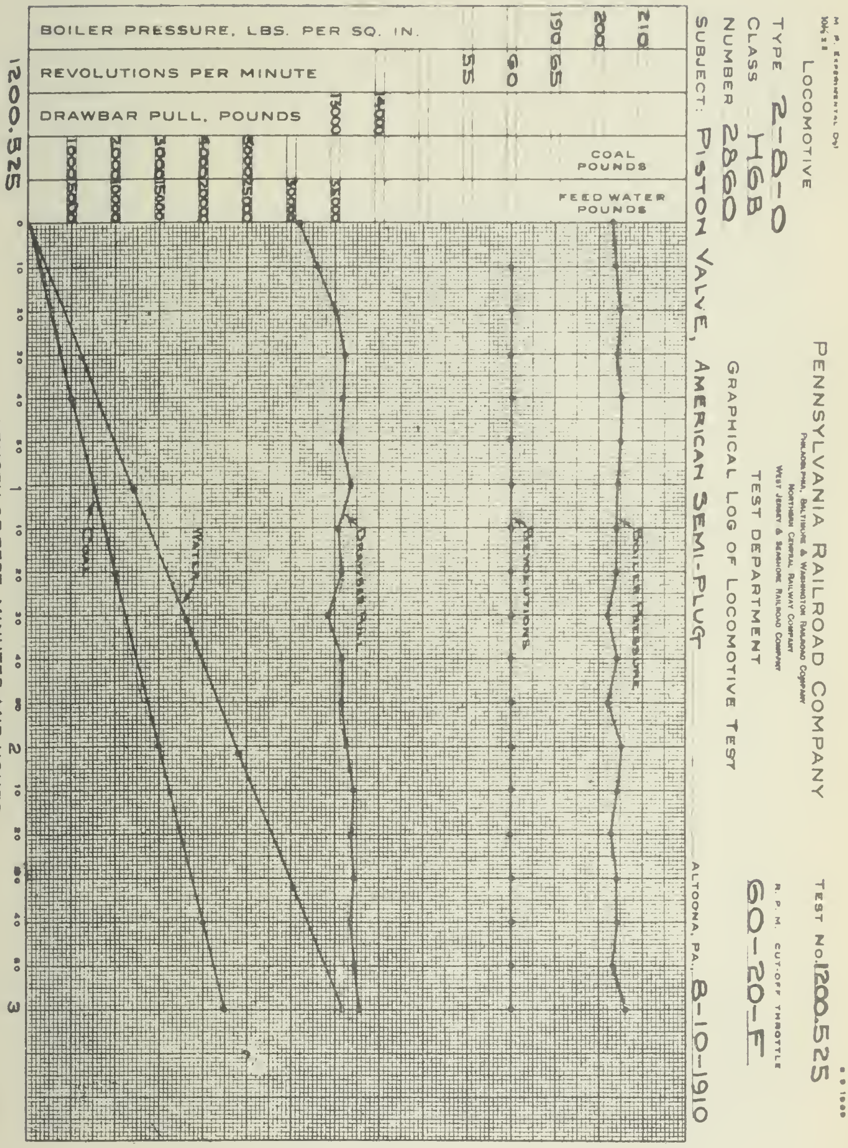
	RUNNING CONDITIONS						BOILER PERFORMANCE				
TEST NUMBER	TEST DESIGNATION	Duration of Test, Hours	Miles per Hour	Throttle Opening, Full or Partial	Actual Cut-off Per Cent., H. P. Cylinders		Pressure in Boiler, Lbs. per Sq. Inch	Draft in Smoke Box, Inches of Water	Draft in Ash Pan, Inches of Water	Calorific Value of Dry Fuel, B. T. U. per Lb.	Cinders Collected in Smoke Box, Pounds per Hour
	R. P. M. Cut-off Throttle	196	199	203	268 to 271		217	222	225	248	238
2209	40-20-F	3	6.6	FULL	19.9		206.6	1.0	0	14444	7
2210	60-20-F	2.5	9.9	"	20.0		204.4	1.4	0	"	10
2211	60-30-F	2.5	9.9	"	31.0		205.9	2.2	0	"	14
2212	80-40-F	2	13.2	"	40.4		204.8	4.3	0	"	37
2213	100-40-F	2	16.5	"	41.2		204.2	5.1	0	"	32
2214	120-40-F	2	19.8	"	41.4		203.5	5.8	0	"	37
2215	140-30-F	2	23.1	"	31.2		205.8	4.2	0	"	45
2216	160-30-F	2	26.4	"	31.0		205.1	4.7	0	"	53

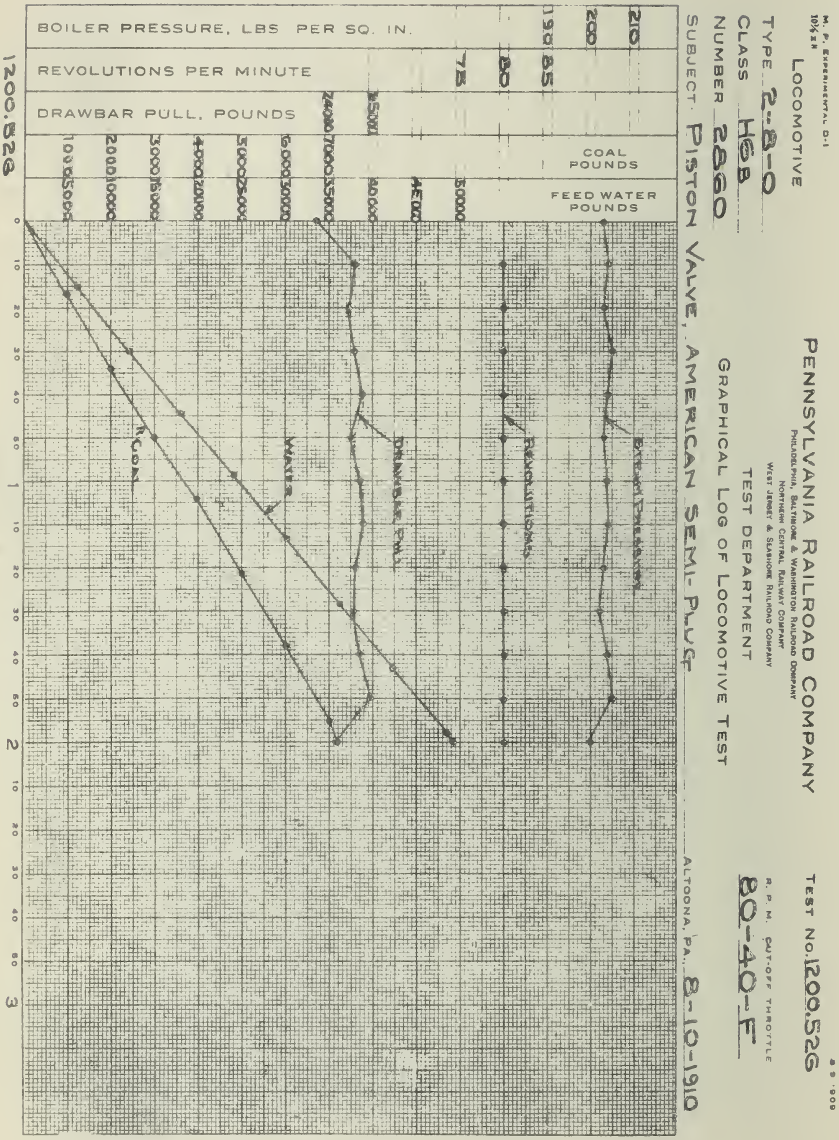
	BOILER PERFORMANCE			EQUIVALENT EVAPORATION FROM AND AT 212° F., POUNDS						ENGINE PERFORMANCE	
TEST NUMBER	Dry Fuel Fired per Hour, Pounds	Dry Fuel per Hour, Pounds per Sq. Ft. of Grate	Water Delivered to Boiler, Pounds per Hour	Per Hour	Per Hour per Sq. Ft. of Fire Heating Sur.	Per Pound of Dry Fuel	Boiler Horse Power (34½ U. of E.)	Efficiency of Boiler, Based on Fuel		Pressure in Branch Pipe, Pounds per Sq. In.	Superheat in Branch Pipe Degrees F.
	338	336	340	344	345	347	349	350		220	230
2209	1257	25.0	11314	13804	5.4	10.7	391.4	72.1			
2210	1464	29.2	12390	14702	5.9	10.0	426.2	67.4			
2211	1899	37.8	16326	19606	7.8	10.3	568.3	69.3			
2212	3188	63.5	24808	29770	11.9	9.3	862.9	62.7			
2213	3888	77.4	27994	33612	13.4	8.7	974.3	58.1			
2214	4400	87.6	30785	37074	14.8	8.4	1074.6	56.6			
2215	3384	67.4	25915	31199	12.4	9.2	904.5	61.9			
2216	3542	70.5	28984	32535	13.0	9.2	943.0	61.7			

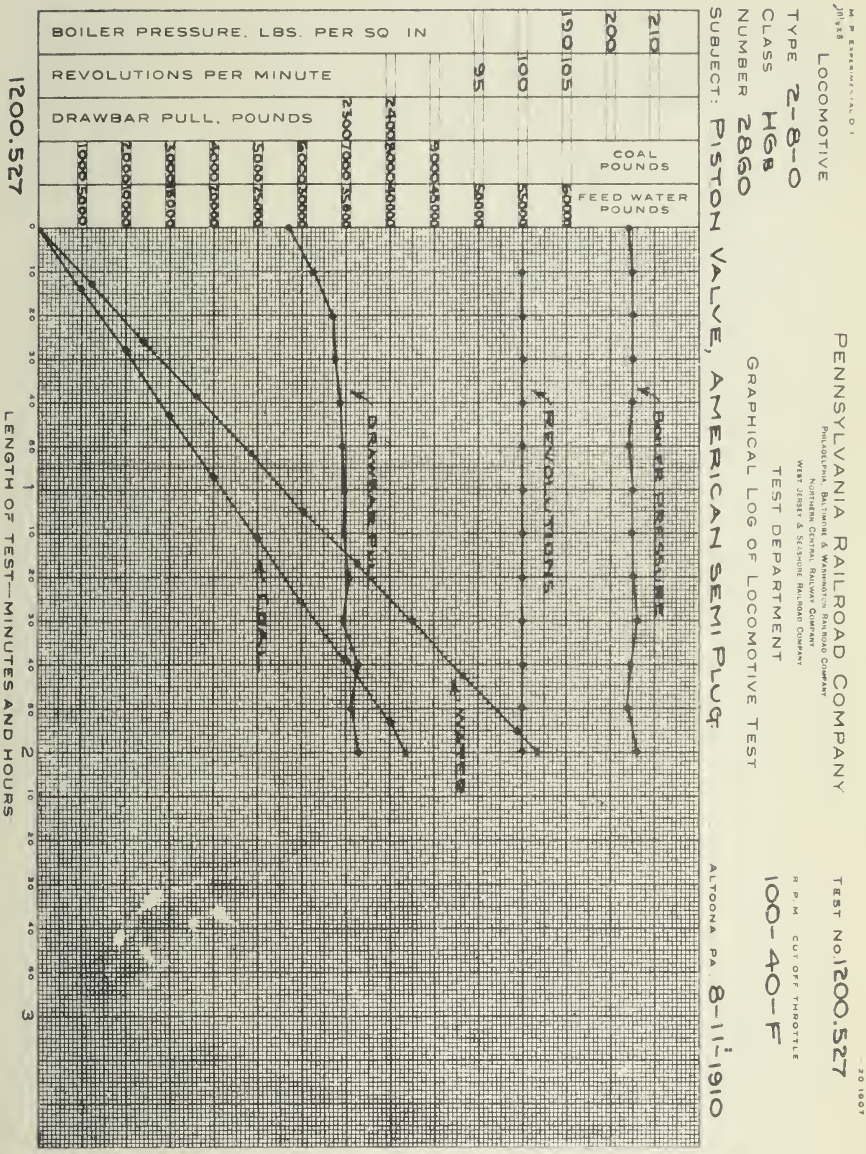
	ENGINE PERFORMANCE					LOCOMOTIVE PERFORMANCE						
TEST NUMBER	Dry Steam to Engines, Pounds per Hour	Indicated Horse Power	Dry Fuel per Indicated Horse Power Hour, Pounds	Dry Steam per Indicated Horse Power Hour, Pounds		Drawbar Pull, Pounds	Dynamometer or Drawbar Horse Power	Dry Fuel per Dynamom. Horse Power Hour, Pounds	Dry Steam per Dynamom. Horse Power Hour, Pounds	Machine Efficiency of Locomotive, Per Cent.	Thermal Efficiency of Locomotive, per Cent., (Based on Fuel)	
	214	379	380	381		265	383	384	385	398	399	
2209	10667	289.5	4.3	36.9		13236	233.1	5.4	45.8	80.5	3.3	
2210	12361	422.0	3.5	29.3		12693	335.3	4.4	36.9	79.5	4.0	
2211	15902	597.9	3.2	26.6		19522	515.7	3.7	30.8	86.3	4.8	
2212	24790	968.1	3.3	25.6		24493	862.7	3.7	28.7	89.1	4.8	
2213	27821	1106.6	3.5	25.1		22128	974.3	4.0	28.6	88.0	4.4	
2214	30785	1212.1	3.6	25.4		19793	1045.8	4.2	29.4	86.3	4.2	
2215	25792	1059.3	3.2	24.4		14820	913.5	3.7	28.2	86.2	4.8	
2216	26850	1128.3	3.1	23.9		13438	946.7	3.7	28.5	83.8	4.7	

RESULTS OF TESTS WITH AMERICAN VALVES ON LOCOMOTIVE 884.
Table 5.

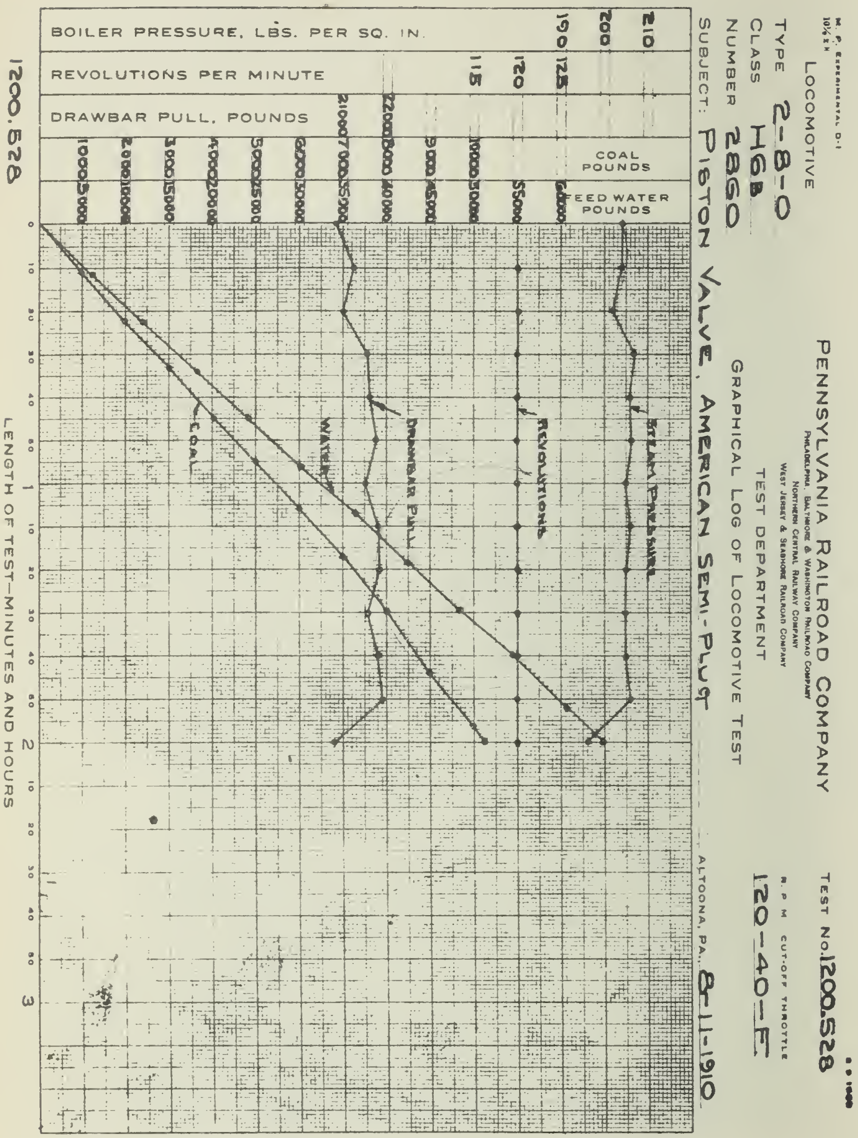

M. P. Experimental D-1
Locomotive
Type 2-8-0
Class H6B
Number 2860
Pennsylvania Railroad Company
Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company
Test Department
Graphical Log of Locomotive Test
Test No. 1200.524
R. P. M. Cut-off Throttle
40-20-F
Subject: Piston Valves American Semi-Plug
Altoona, Pa., 8-9-1910
Boiler Pressure, Lbs. per Sq. In.
Revolutions per Minute
Drawbar Pull, Pounds
Coal Pounds
Feed Water Pounds
210
200
190
45
40
35
13000
12000
30000
25000
4000
20000
3000
15000
2000
10000
1000
5000
Boiler Pressure
Revolutions
Drawbar Pull
Water
Coal
1200.524
Length of Test—Minutes and Hours

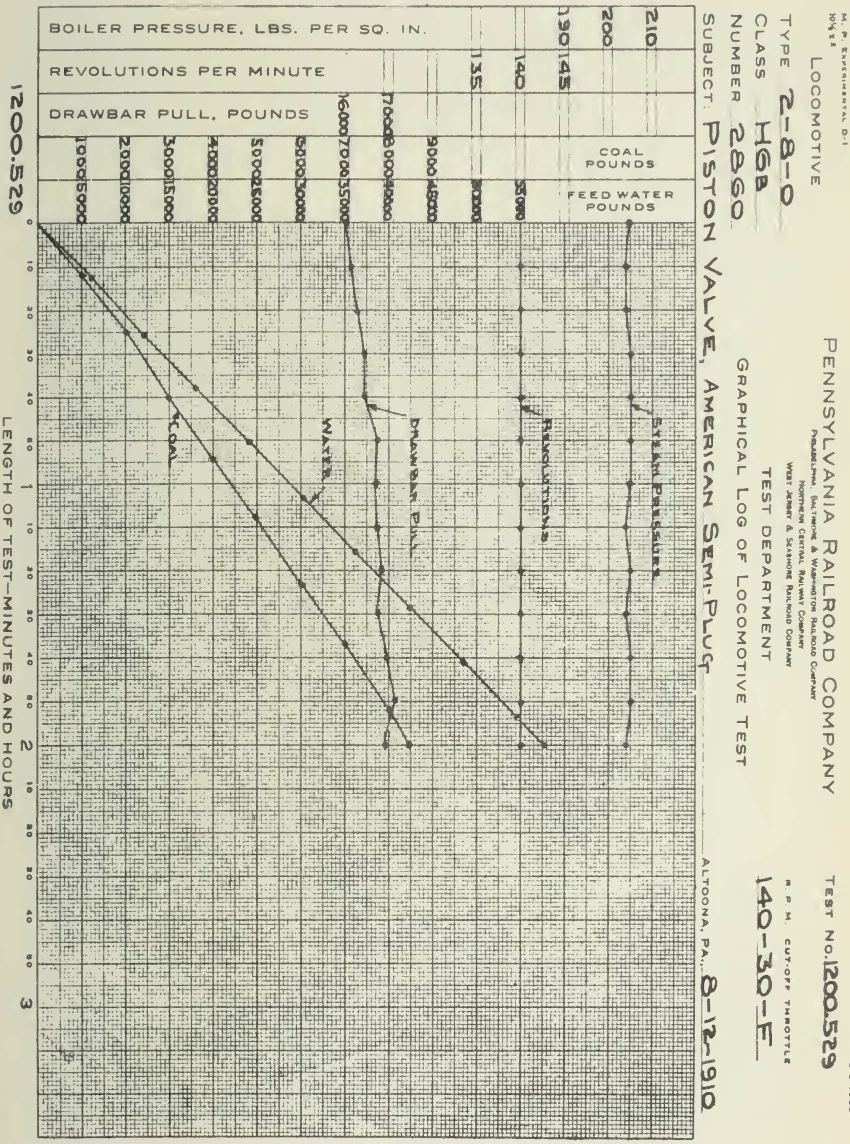

PENNSYLVANIA RAILROAD COMPANY
PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY
TEST DEPARTMENT
GRAPHICAL LOG OF LOCOMOTIVE TEST
TEST No. 1200.525
R. P. M. CUT-OFF THROTTLE
60-20-F
LOCOMOTIVE
TYPE 2-8-0
CLASS H6B
NUMBER 2860
SUBJECT: PISTON VALVE, AMERICAN SEMI-PLUG
ALTOONA, PA., 8-10-1910
BOILER PRESSURE, LBS. PER SQ. IN.
REVOLUTIONS PER MINUTE
DRAWBAR PULL, POUNDS
COAL POUNDS
FEED WATER POUNDS
1200.525
BOILER PRESSURE
REVOLUTIONS
DRAWBAR PULL
WATER
COAL
LENGTH OF TEST—MINUTES AND HOURS

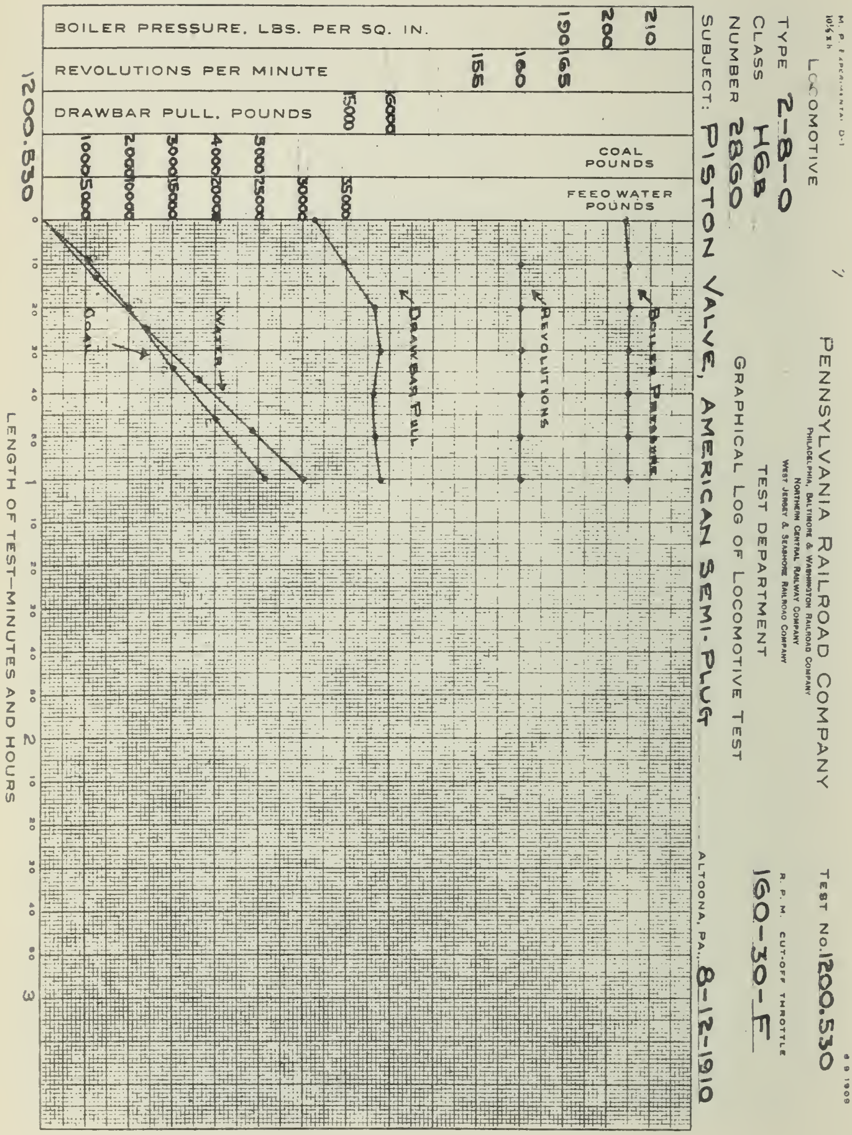

M. P. Experimental D-1
Locomotive
Type 2-8-0
Class H6B
Number 2860
Subject Piston Valve, American Semi-Plug
Altoona, Pa. 8-10-1910
Pennsylvania Railroad Company
Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company
Test Department
Graphical Log of Locomotive Test
Test No. 1200.526
R. P. M. Cut-off Throttle
80-40-F
Boiler Pressure, Lbs per Sq. In.
Revolutions per Minute
Drawbar Pull, Pounds
Coal Pounds
Feed Water Pounds
Steam Pressure
Revolutions
Drawbar Pull
Water
Coal
Length of Test—Minutes and Hours
1200.526

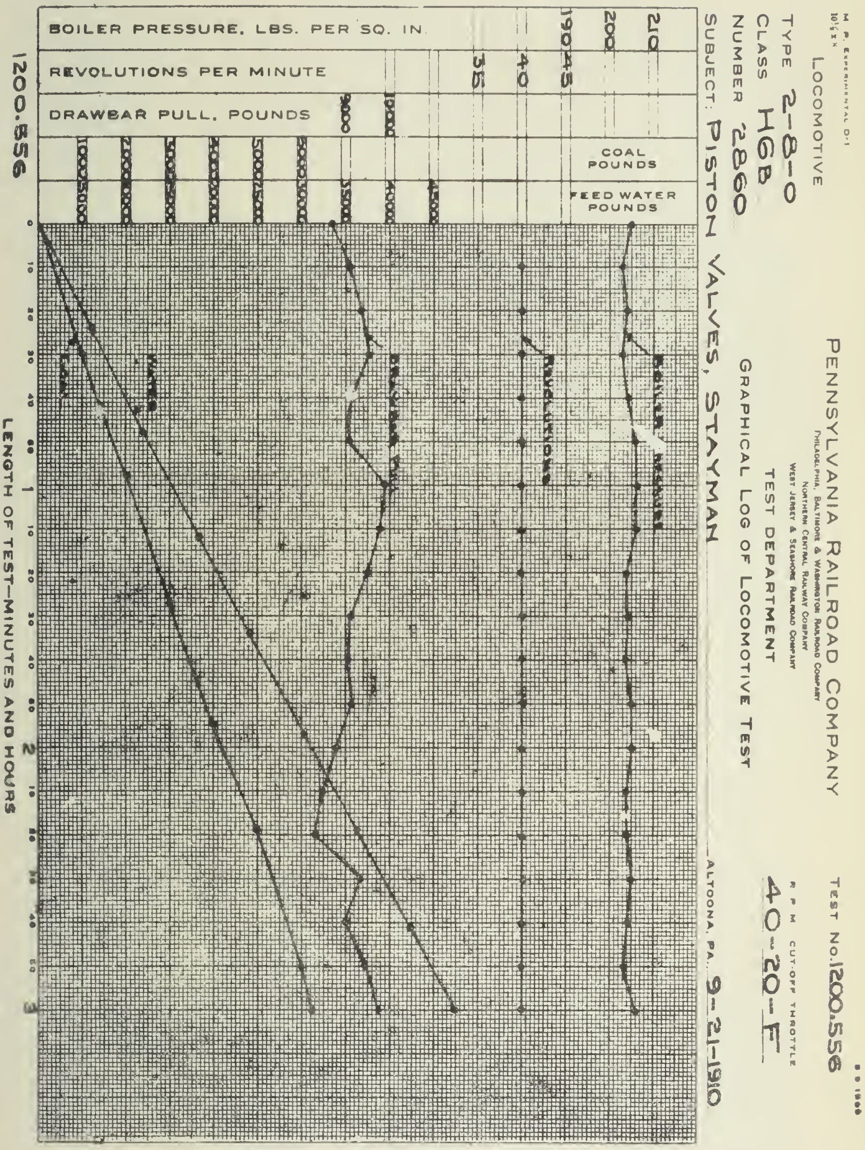


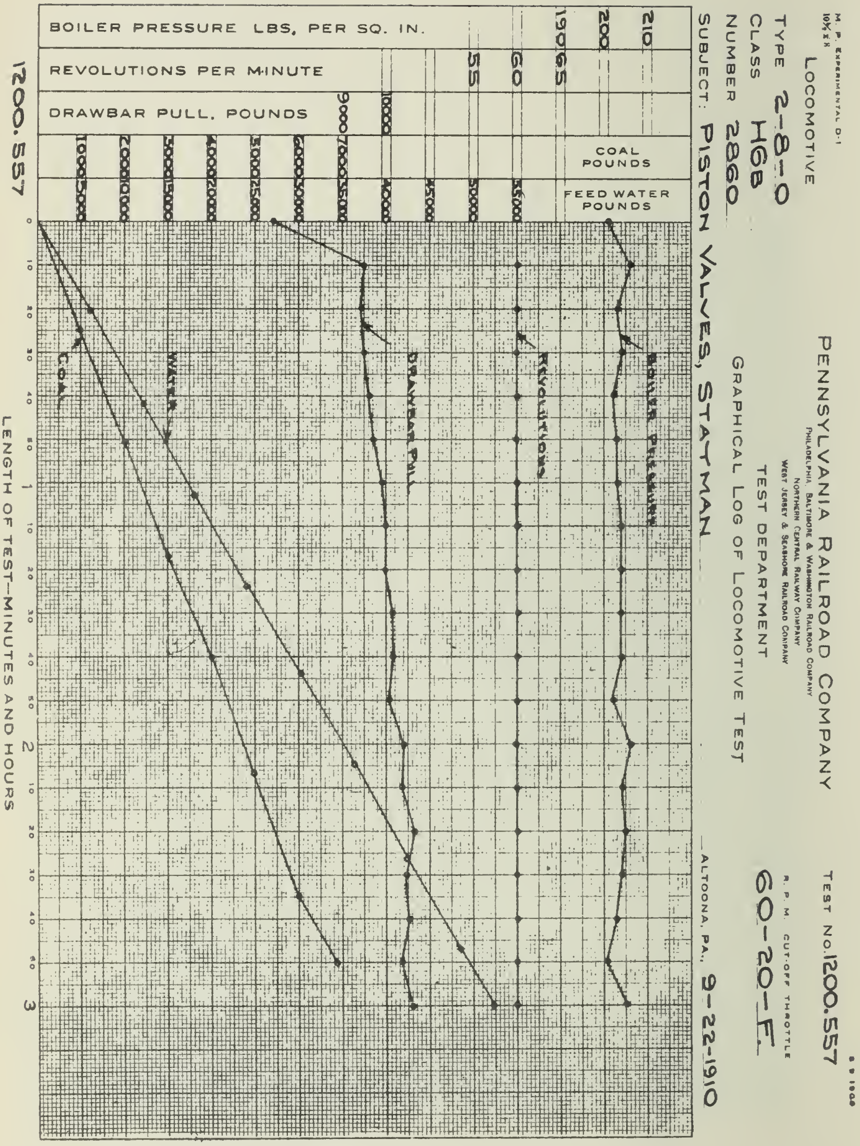
PENNSYLVANIA RAILROAD COMPANY
Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company
TEST DEPARTMENT
GRAPHICAL LOG OF LOCOMOTIVE TEST
TEST No. 1200.527
R.P.M. CUT OFF THROTTLE
100-40-F
LOCOMOTIVE
TYPE 2-8-0
CLASS H6B
NUMBER 2860
SUBJECT: PISTON VALVE, AMERICAN SEMI PLUG
ALTOONA PA. 8-11-1910
BOILER PRESSURE, LBS. PER SQ IN
REVOLUTIONS PER MINUTE
DRAWBAR PULL, POUNDS
COAL POUNDS
FEED WATER POUNDS
BOILER PRESSURE
REVOLUTIONS
DRAWBAR PULL
COAL
WATER
LENGTH OF TEST—MINUTES AND HOURS
1200.527

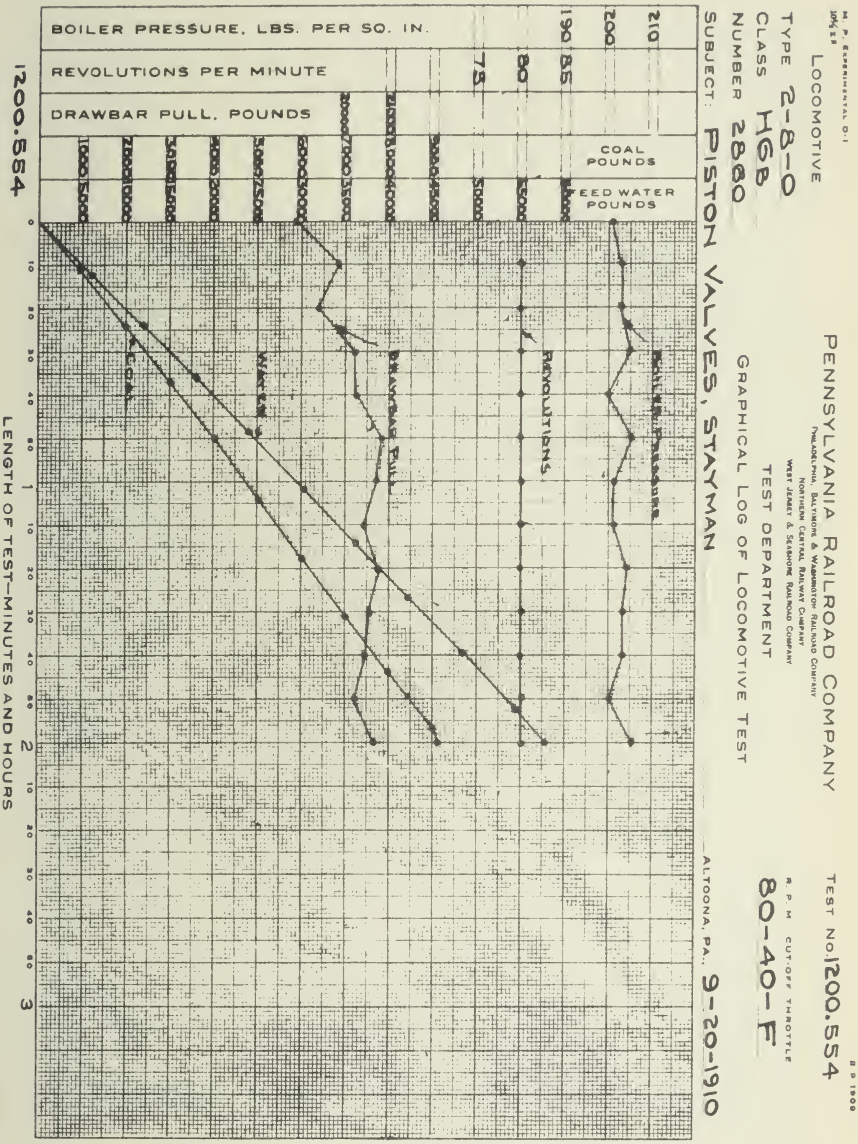

Pennsylvania Railroad Company
Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company
Test Department
Graphical Log of Locomotive Test
Test No. 1200.528
R. P. M. Cut-off Throttle
120-40-F
Locomotive
Type 2-8-0
Class H6b
Number 2860
Subject: Piston Valve, American Semi-Plug
Altoona, Pa. 8-11-1910
Boiler Pressure, Lbs. per sq. in.
Revolutions per Minute
Drawbar Pull, Pounds
Coal Pounds
Feed Water Pounds
Steam Pressure
Revolutions
Drawbar Pull
Water
Coal
Length of Test—Minutes and Hours
1200.528

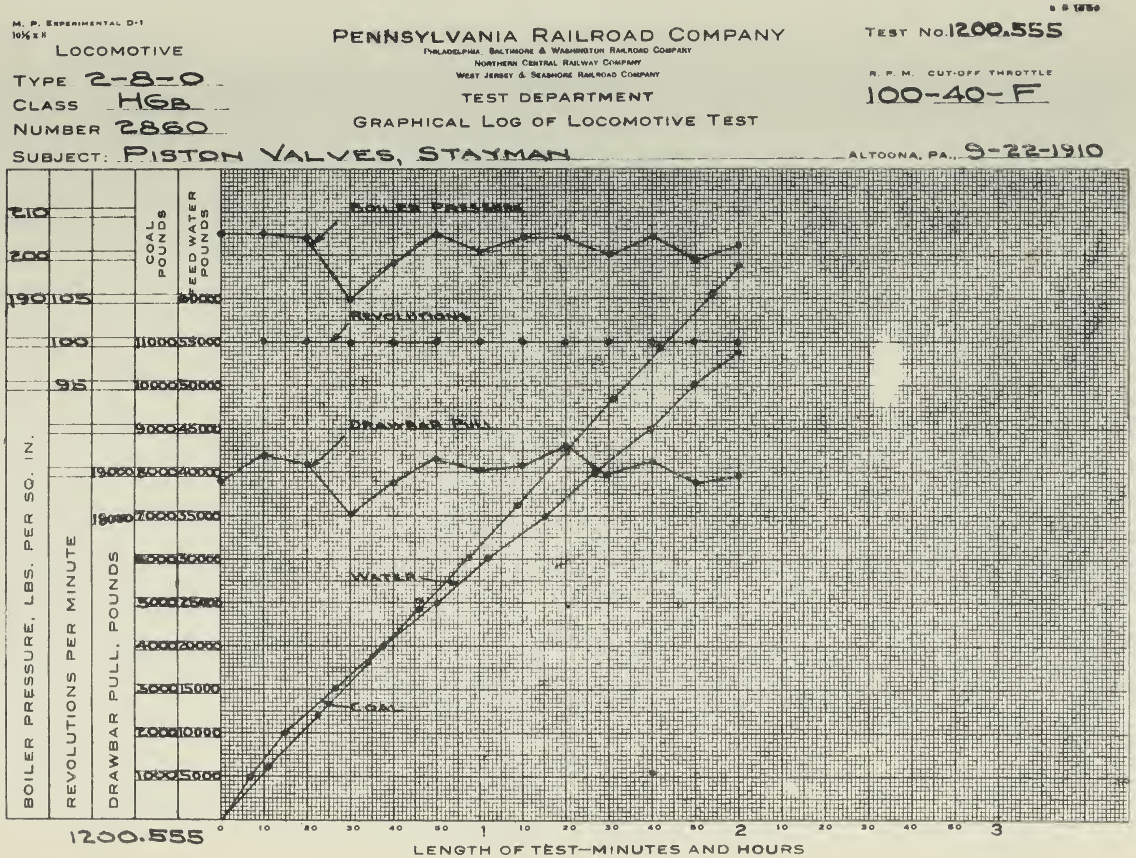

LOCOMOTIVE
TYPE 2-8-0
CLASS H6B
NUMBER 2860
SUBJECT: PISTON VALVE, AMERICAN SEMI-PLUG
PENNSYLVANIA RAILROAD COMPANY
TEST DEPARTMENT
GRAPHICAL LOG OF LOCOMOTIVE TEST
TEST No. 1200.529
R. P. M. CUT-OFF THROTTLE
140-30-F
ALTOONA, PA., 8-12-1910
BOILER PRESSURE, LBS. PER SQ. IN.
REVOLUTIONS PER MINUTE
DRAWBAR PULL, POUNDS
COAL POUNDS
FEED WATER POUNDS
STEAM PRESSURE
REVOLUTIONS
DRAWBAR PULL
WATER
COAL
LENGTH OF TEST—MINUTES AND HOURS
1200.529

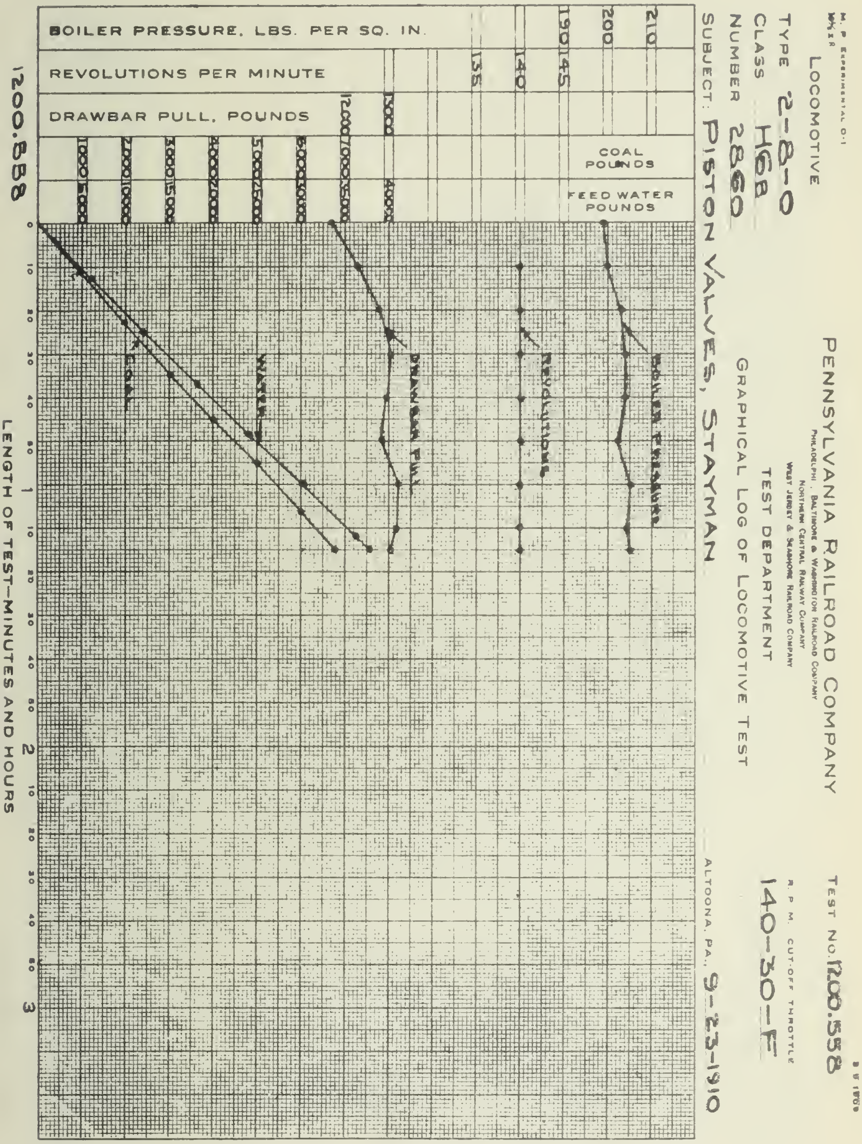

PENNSYLVANIA RAILROAD COMPANY
PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY
TEST DEPARTMENT
GRAPHICAL LOG OF LOCOMOTIVE TEST
TEST No. 1200.530
R. P. M. CUT-OFF THROTTLE
160-30-F
LOCOMOTIVE
TYPE 2-8-0
CLASS H6B
NUMBER 2860
SUBJECT: PISTON VALVE, AMERICAN SEMI-PLUG
ALTOONA, PA. 8-12-1910
BOILER PRESSURE, LBS. PER SQ. IN.
REVOLUTIONS PER MINUTE
DRAWBAR PULL, POUNDS
COAL POUNDS
FEED WATER POUNDS
BOILER PRESSURE
REVOLUTIONS
DRAWBAR PULL
WATER
COAL
LENGTH OF TEST—MINUTES AND HOURS
1200.530

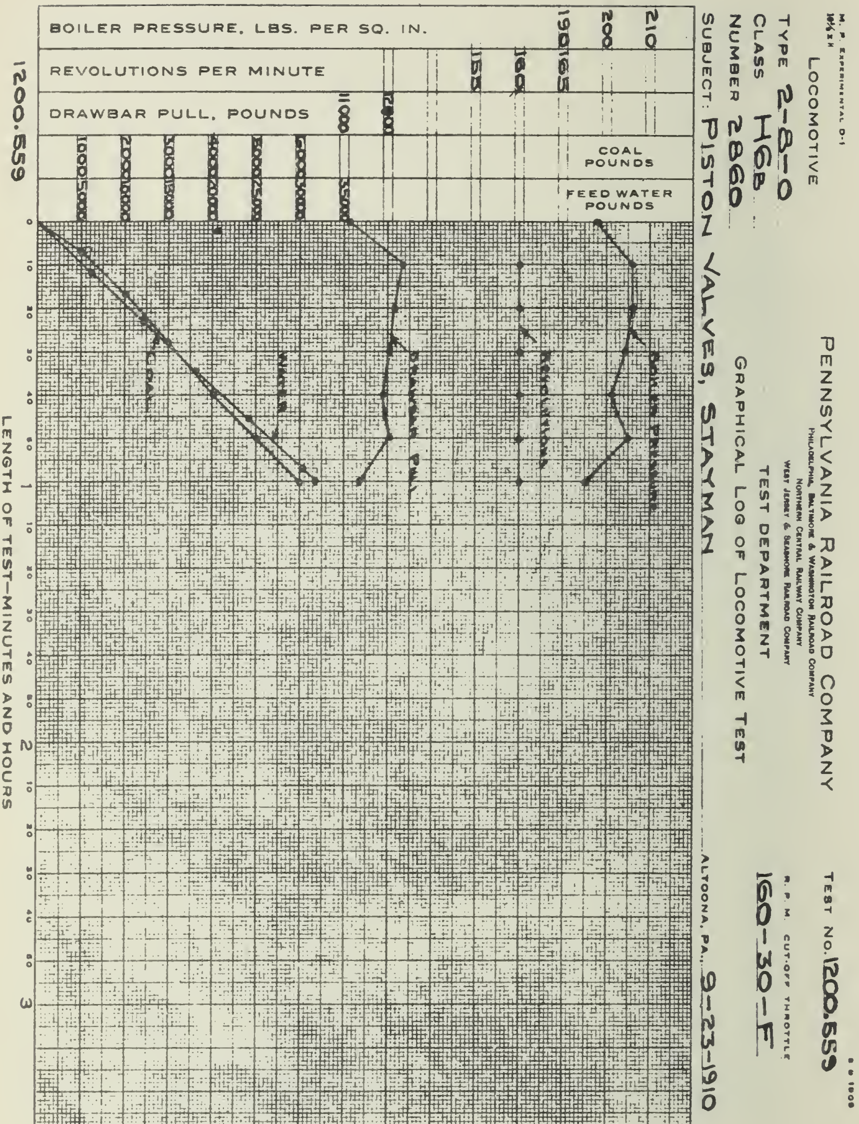

PENNSYLVANIA RAILROAD COMPANY
PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY
TEST DEPARTMENT
GRAPHICAL LOG OF LOCOMOTIVE TEST
TEST No. 1200.556
R P M CUT-OFF THROTTLE
40 - 20 - F
LOCOMOTIVE
TYPE 2-8-0
CLASS H6B
NUMBER 2860
SUBJECT: PISTON VALVES, STAYMAN
ALTOONA, PA. 9-21-1910
BOILER PRESSURE, LBS. PER SQ. IN.
REVOLUTIONS PER MINUTE
DRAWBAR PULL, POUNDS
COAL POUNDS
FEED WATER POUNDS
210
200
190
45
40
35
BOILER PRESSURE
REVOLUTIONS
DRAWBAR PULL
WATER
COAL
LENGTH OF TEST—MINUTES AND HOURS
1200.556

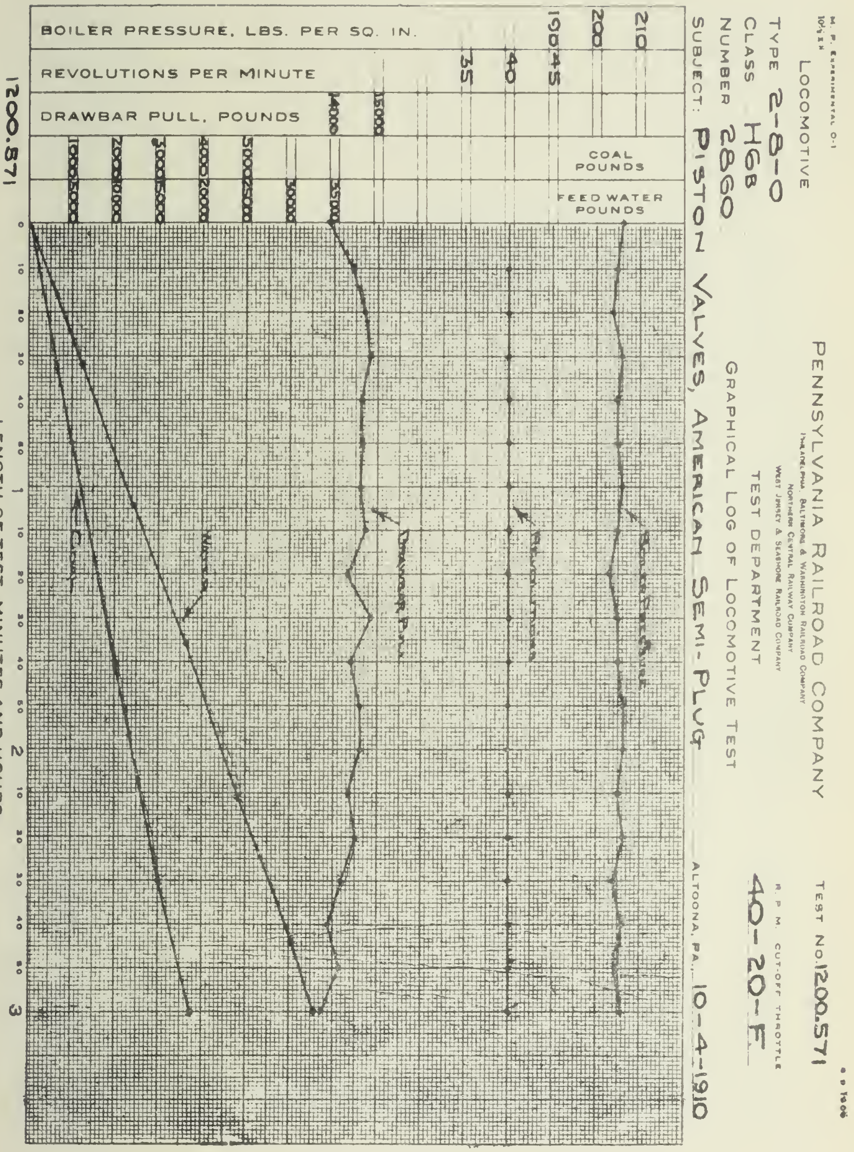

M. P. Experimental D-1
Locomotive
Type 2-8-0
Class H6B
Number 2860
Subject: Piston Valves, Statman
Pennsylvania Railroad Company
Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company
Test Department
Graphical Log of Locomotive Test
Test No. 1200.557
R. P. M. Cut-off Throttle
60-20-F.
Altoona, Pa., 9-22-1910
Boiler Pressure Lbs. per Sq. In.
Revolutions per Minute
Drawbar Pull, Pounds
Coal Pounds
Feed Water Pounds
Boiler Pressure
Revolutions
Drawbar Pull
Water
Coal
Length of Test—Minutes and Hours
1200.557

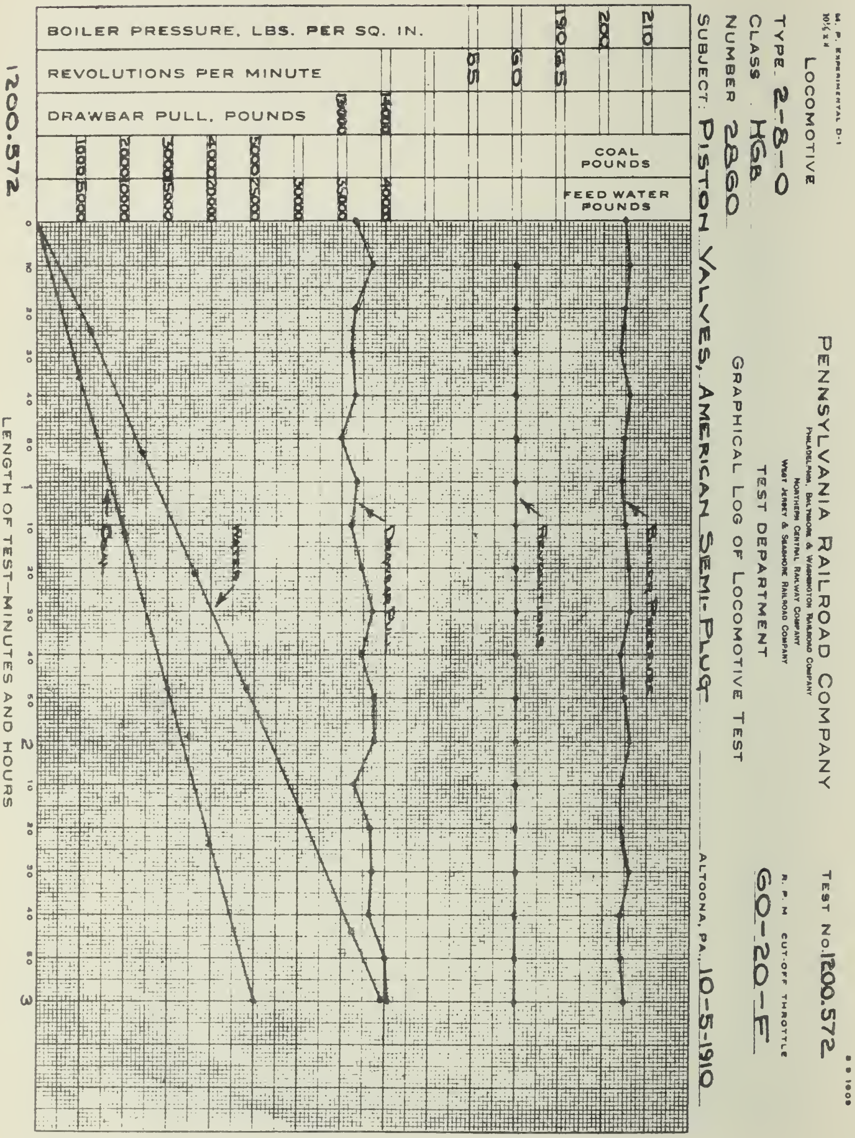

LOCOMOTIVE
TYPE 2-8-0
CLASS H6B
NUMBER 2880
SUBJECT: PISTON VALVES, STAYMAN
PENNSYLVANIA RAILROAD COMPANY
PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY
TEST DEPARTMENT
GRAPHICAL LOG OF LOCOMOTIVE TEST
TEST No. 1200.554
R. P. M. CUT-OFF THROTTLE
80-40-F
ALTOONA, PA., 9-20-1910
BOILER PRESSURE, LBS. PER SQ. IN.
REVOLUTIONS PER MINUTE
DRAWBAR PULL, POUNDS
COAL POUNDS
FEED WATER POUNDS
210
200
190
85
80
75
BOILER PRESSURE
REVOLUTIONS
DRAWBAR PULL
WATER
COAL
1
2
3
LENGTH OF TEST—MINUTES AND HOURS
1200.554

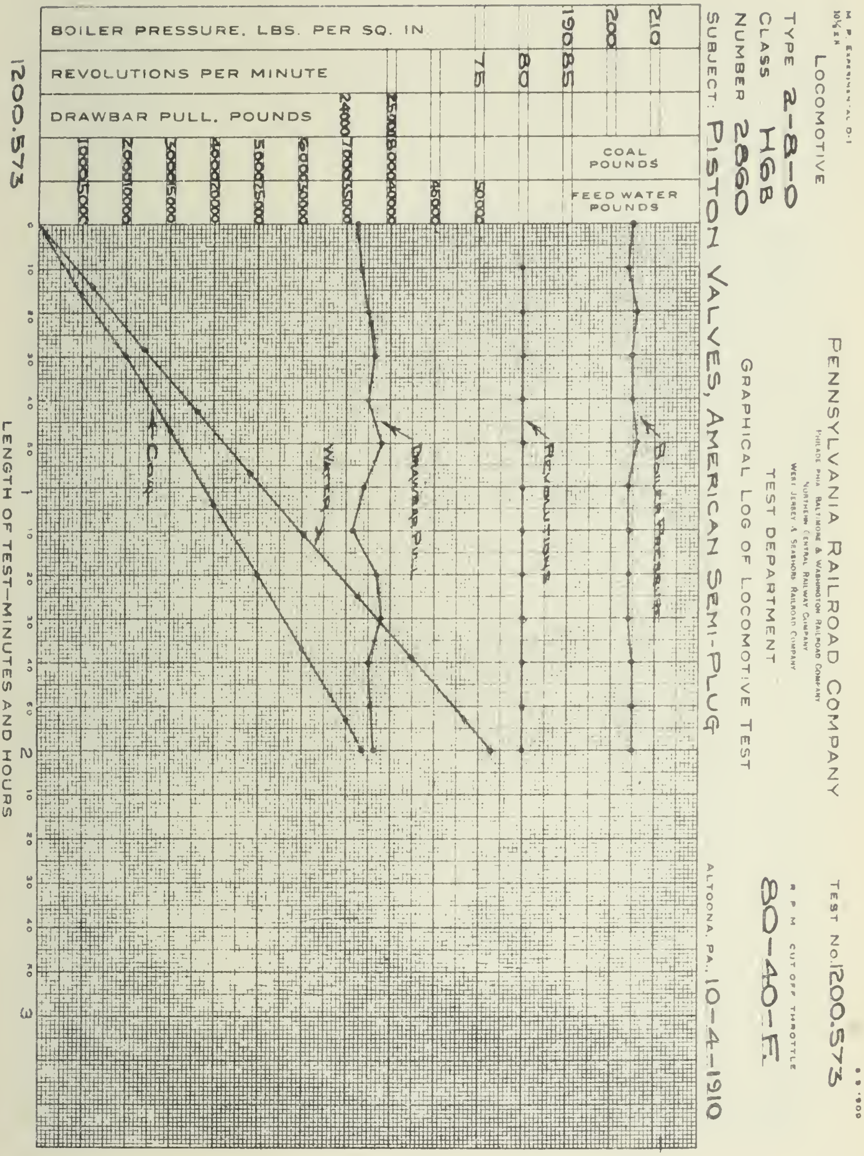

M. P. Experimental D-1
Locomotive
Type 2-8-0
Class H6b
Number 2860
Subject: Piston Valves, Stayman
Pennsylvania Railroad Company
Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company
Test Department
Graphical Log of Locomotive Test
Test No. 1200.555
R. P. M. Cut-off Throttle
100-40-F
Altoona, Pa., 9-22-1910
Boiler Pressure, Lbs. per Sq. In.
Revolutions per Minute
Drawbar Pull, Pounds
Coal Pounds
Feed Water Pounds
210
200
190
105
100
95
19000
18000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
60000
55000
50000
45000
40000
35000
30000
25000
20000
15000
10000
5000
Boiler Pressure
Revolutions
Drawbar Pull
Water
Coal
0
10
20
30
40
50
1
2
3
1200.555
Length of Test—Minutes and Hours

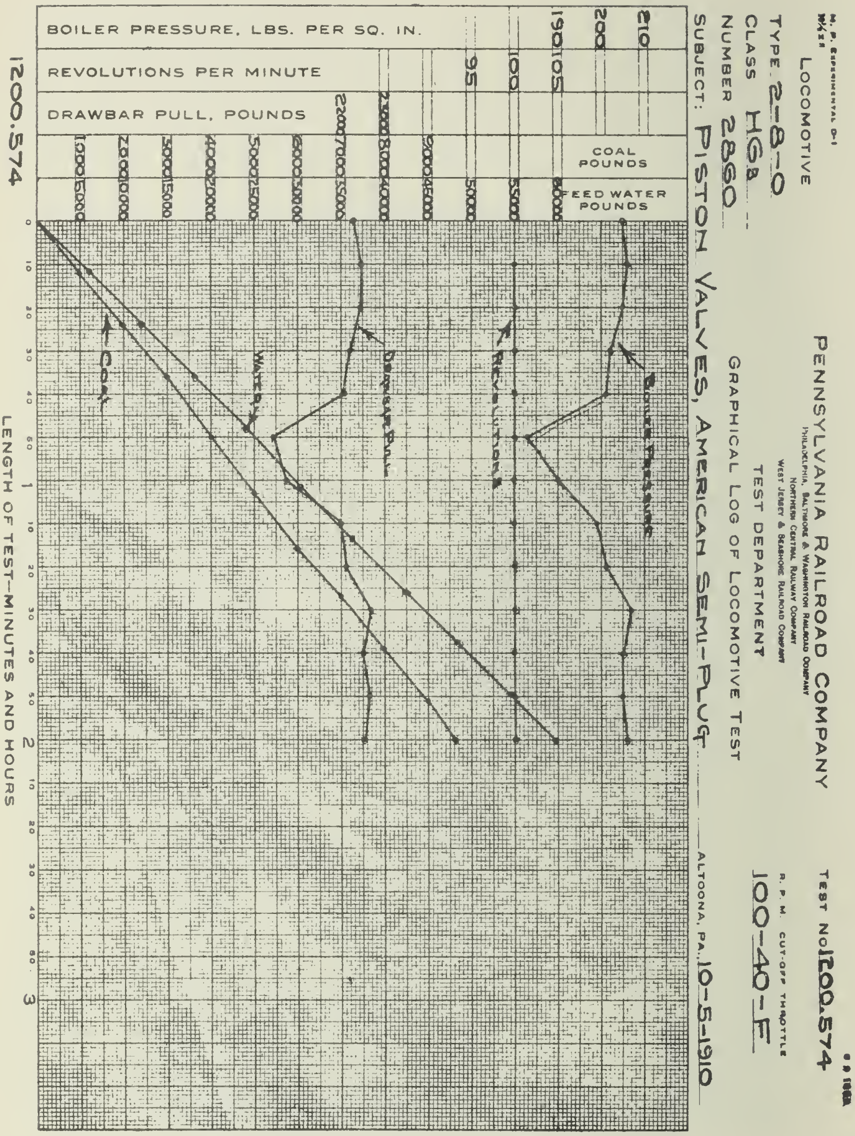

PENNSYLVANIA RAILROAD COMPANY
PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY
TEST DEPARTMENT
GRAPHICAL LOG OF LOCOMOTIVE TEST
LOCOMOTIVE
TYPE 2-8-0
CLASS H6B
NUMBER 2860
SUBJECT: PISTON VALVES, STAYMAN
TEST NO. 1200.558
R. P. M. CUT-OFF THROTTLE
140-30-F
ALTOONA, PA., 9-23-1910
BOILER PRESSURE, LBS. PER SQ. IN.
REVOLUTIONS PER MINUTE
DRAWBAR PULL, POUNDS
COAL POUNDS
FEED WATER POUNDS
BOILER PRESSURE
REVOLUTIONS
DRAWBAR PULL
WATER
COAL
LENGTH OF TEST—MINUTES AND HOURS
1200.888

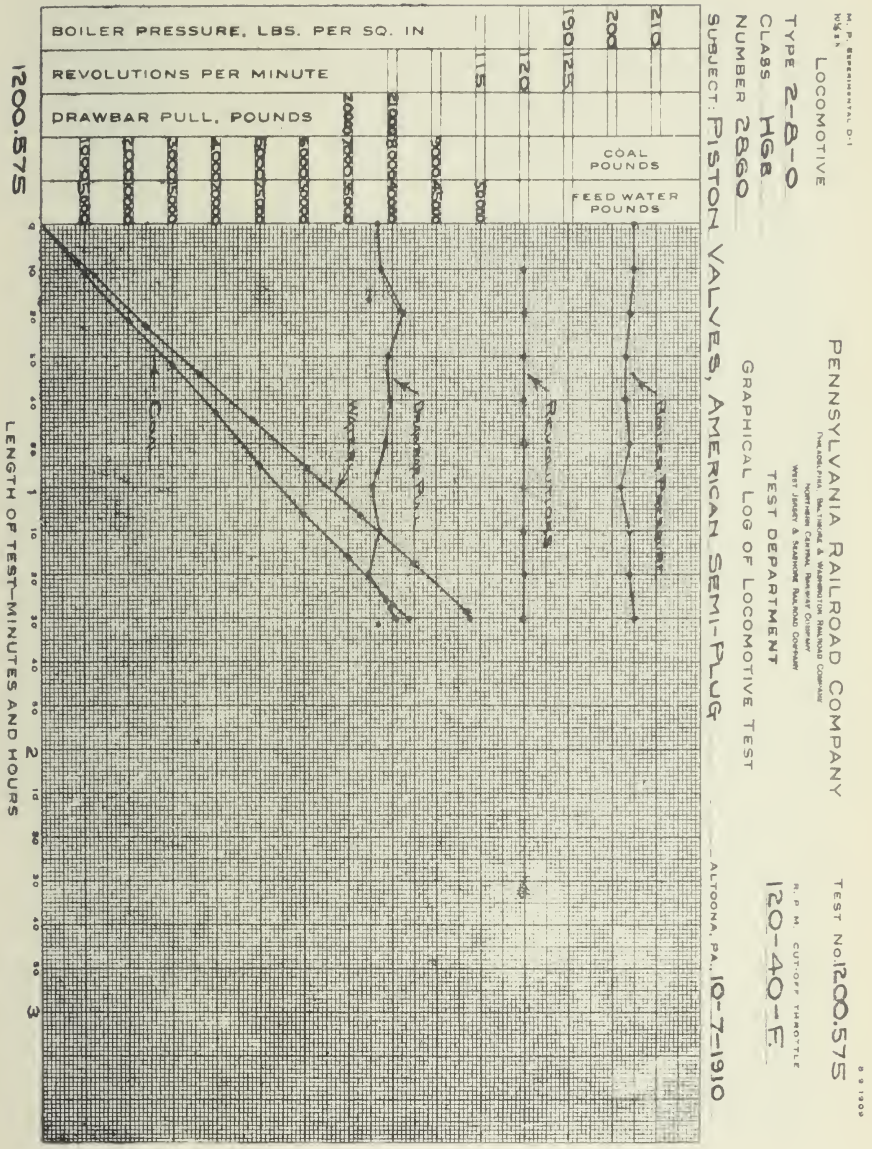

PENNSYLVANIA RAILROAD COMPANY
PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY
TEST DEPARTMENT
GRAPHICAL LOG OF LOCOMOTIVE TEST
TEST No. 1200.559
LOCOMOTIVE
TYPE 2-8-0
CLASS H6B
NUMBER 2860
SUBJECT: PISTON VALVES, STAYMAN
ALTOONA, PA., 9-23-1910
R. P. M. CUT-OFF THROTTLE
160-30-F
BOILER PRESSURE, LBS. PER SQ. IN.
REVOLUTIONS PER MINUTE
DRAWBAR PULL, POUNDS
COAL POUNDS
FEED WATER POUNDS
BOILER PRESSURE
REVOLUTIONS
DRAWBAR PULL
WATER
COAL
LENGTH OF TEST—MINUTES AND HOURS
1200.559

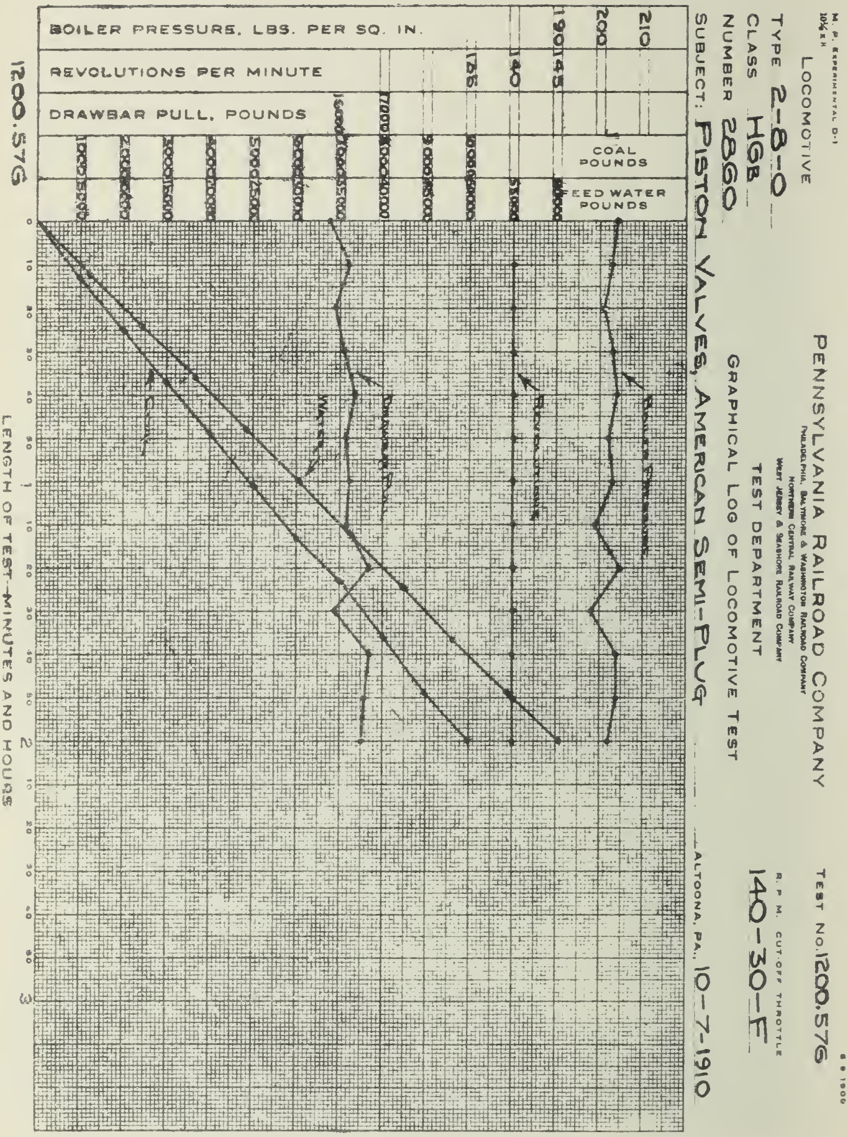

LOCOMOTIVE
TYPE 2-8-0
CLASS H6B
NUMBER 2860
SUBJECT: PISTON VALVES, AMERICAN SEMI-PLUG
PENNSYLVANIA RAILROAD COMPANY
TEST DEPARTMENT
GRAPHICAL LOG OF LOCOMOTIVE TEST
TEST No. 1200.571
R. P. M. CUT-OFF THROTTLE
40-20-F
ALTOONA, PA. 10-4-1910
BOILER PRESSURE, LBS. PER SQ. IN.
REVOLUTIONS PER MINUTE
DRAWBAR PULL, POUNDS
COAL POUNDS
FEED WATER POUNDS
210
200
190
45
40
35
15000
14000
1200.571
LENGTH OF TEST—MINUTES AND HOURS
1
2
3

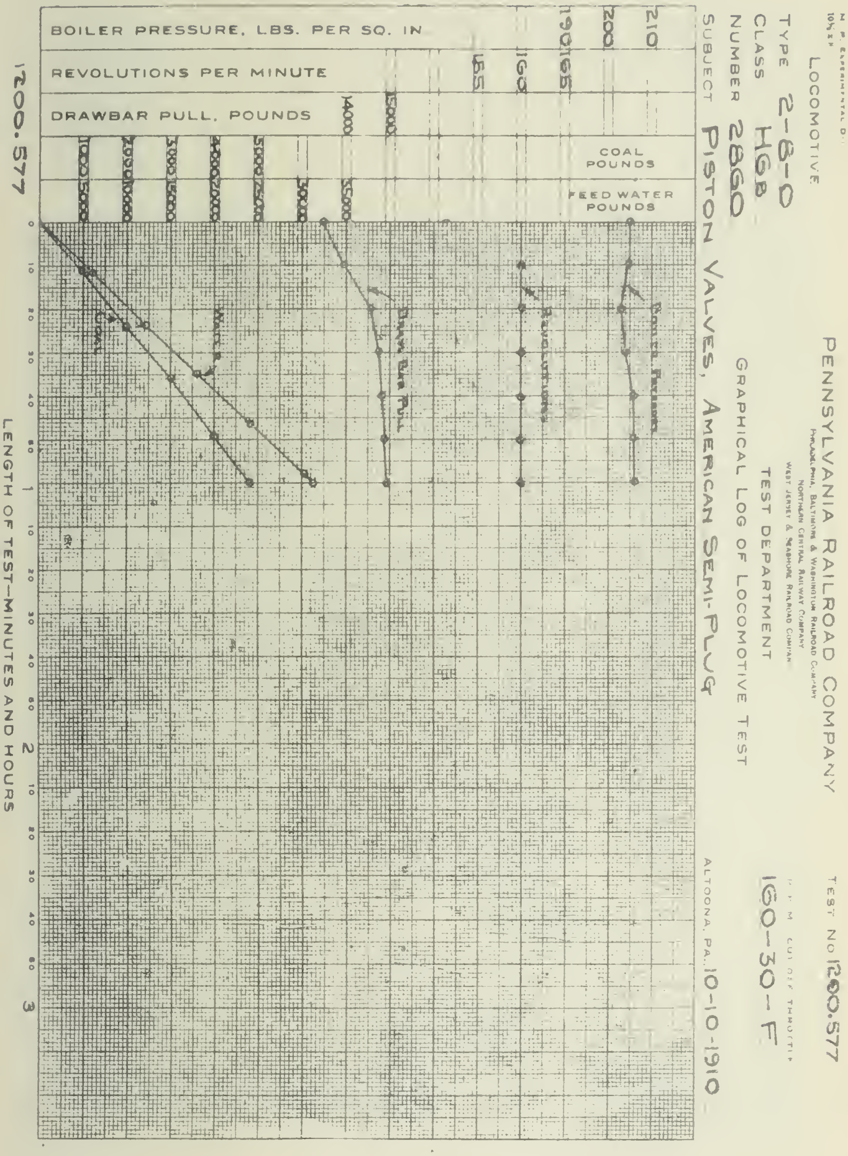

M. P. EXPERIMENTAL D-1
LOCOMOTIVE
TYPE 2-8-0
CLASS H6B
NUMBER 2860
SUBJECT: PISTON VALVES, AMERICAN SEMI-PLUG
ALTOONA, PA. 10-5-1910
PENNSYLVANIA RAILROAD COMPANY
PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY
TEST DEPARTMENT
GRAPHICAL LOG OF LOCOMOTIVE TEST
TEST No. 1200.572
R. P. M. CUT-OFF THROTTLE
60-20-F
BOILER PRESSURE, LBS. PER SQ. IN.
REVOLUTIONS PER MINUTE
DRAWBAR PULL, POUNDS
COAL POUNDS
FEED WATER POUNDS
210
200
190
65
60
55
14000
13000
1000
2000
3000
4000
5000
5000
10000
15000
20000
25000
30000
35000
40000
Boiler Pressure
Revolutions
Drawbar Pull
Water
Coal
0 10 20 30 40 50 1 10 20 30 40 50 2 10 20 30 40 50 3
LENGTH OF TEST—MINUTES AND HOURS
1200.572

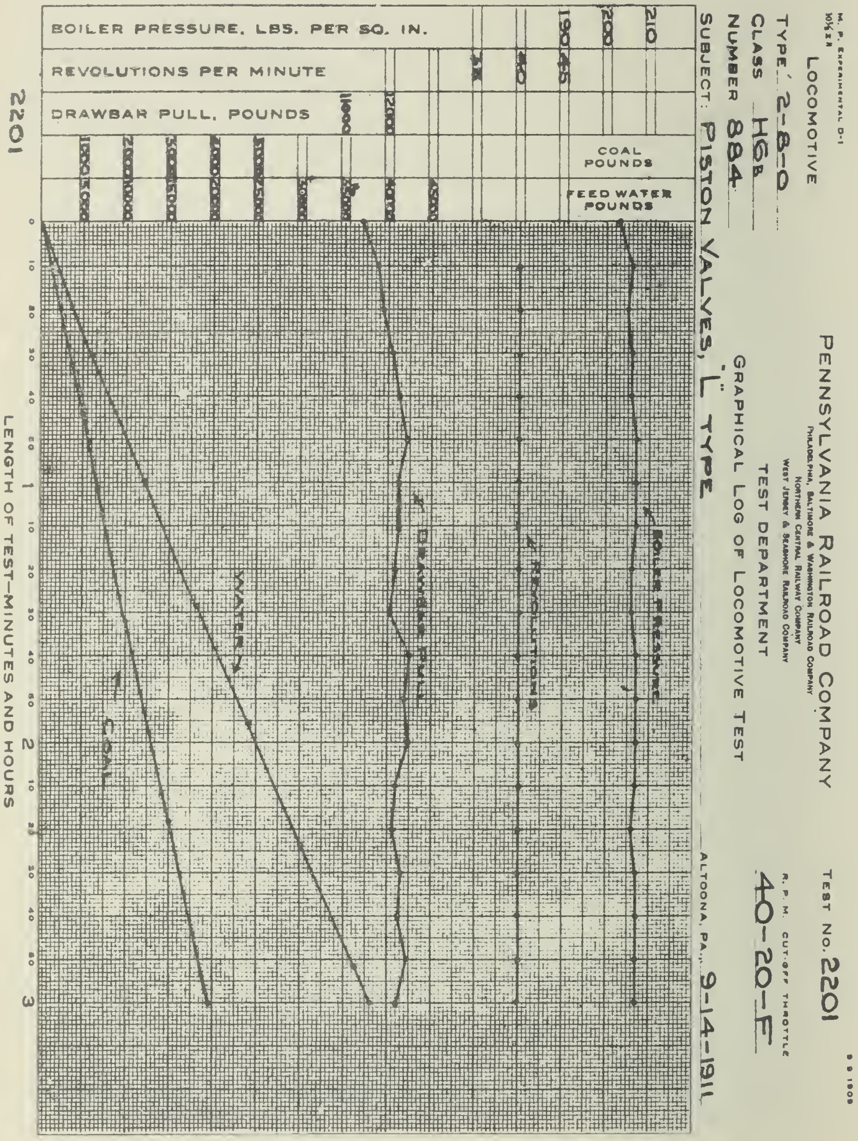

PENNSYLVANIA RAILROAD COMPANY
TEST DEPARTMENT
GRAPHICAL LOG OF LOCOMOTIVE TEST
TEST No. 1200.573
80-40-F.
R P M CUT OFF THROTTLE
ALTOONA, PA., 10-4-1910
LOCOMOTIVE
TYPE 2-8-0
CLASS H6B
NUMBER 2860
SUBJECT: PISTON VALVES, AMERICAN SEMI-PLUG
BOILER PRESSURE, LBS. PER SQ. IN
REVOLUTIONS PER MINUTE
DRAWBAR PULL, POUNDS
COAL POUNDS
FEED WATER POUNDS
Boiler Pressure
Revolutions
Drawbar Pull
Water
Coal
LENGTH OF TEST—MINUTES AND HOURS
1200.573

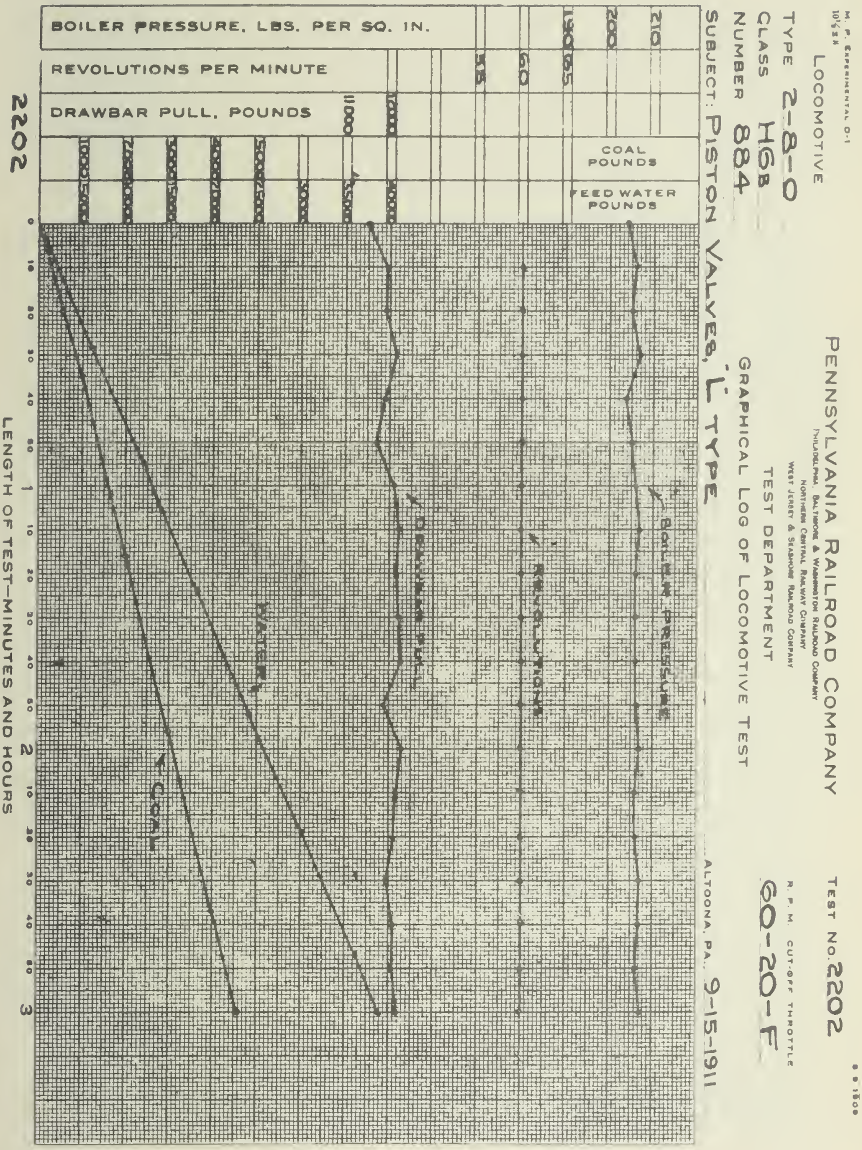

PENNSYLVANIA RAILROAD COMPANY
PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY
TEST DEPARTMENT
GRAPHICAL LOG OF LOCOMOTIVE TEST
TEST No 1200.574
100-40-F
R. P. M. CUT-OFF THROTTLE
LOCOMOTIVE
TYPE 2-8-0
CLASS H6B
NUMBER 2860
SUBJECT: PISTON VALVES, AMERICAN SEMI-PLUG
ALTOONA, PA. 10-5-1910
BOILER PRESSURE, LBS. PER SQ. IN.
REVOLUTIONS PER MINUTE
DRAWBAR PULL, POUNDS
COAL POUNDS
FEED WATER POUNDS
Boiler Pressure
Revolutions
Drawbar Pull
Water
Coal
LENGTH OF TEST-MINUTES AND HOURS
1200.574

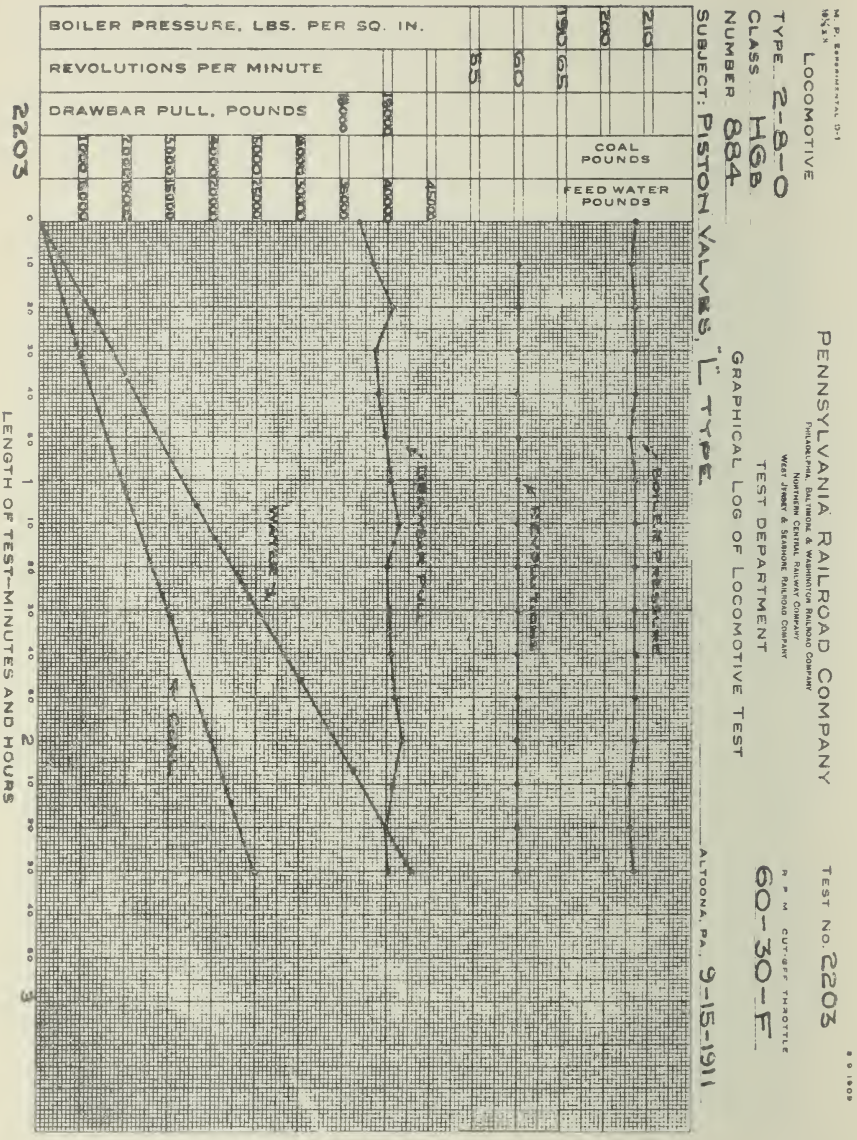

M. P. EXPERIMENTAL D-1
LOCOMOTIVE
TYPE 2-8-0
CLASS H6B
NUMBER 2860
PENNSYLVANIA RAILROAD COMPANY
PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY
TEST DEPARTMENT
GRAPHICAL LOG OF LOCOMOTIVE TEST
TEST No.1200.575
R. P. M. CUT-OFF THROTTLE
120-40-F.
SUBJECT: PISTON VALVES, AMERICAN SEMI-PLUG
ALTOONA, PA. 10-7-1910
BOILER PRESSURE, LBS. PER SQ. IN
REVOLUTIONS PER MINUTE
DRAWBAR PULL, POUNDS
COAL POUNDS
FEED WATER POUNDS
210
200
190
125
120
115
Boiler Pressure
Revolutions
Drawbar Pull
Water
Coal
LENGTH OF TEST—MINUTES AND HOURS
1
2
3
1200.575

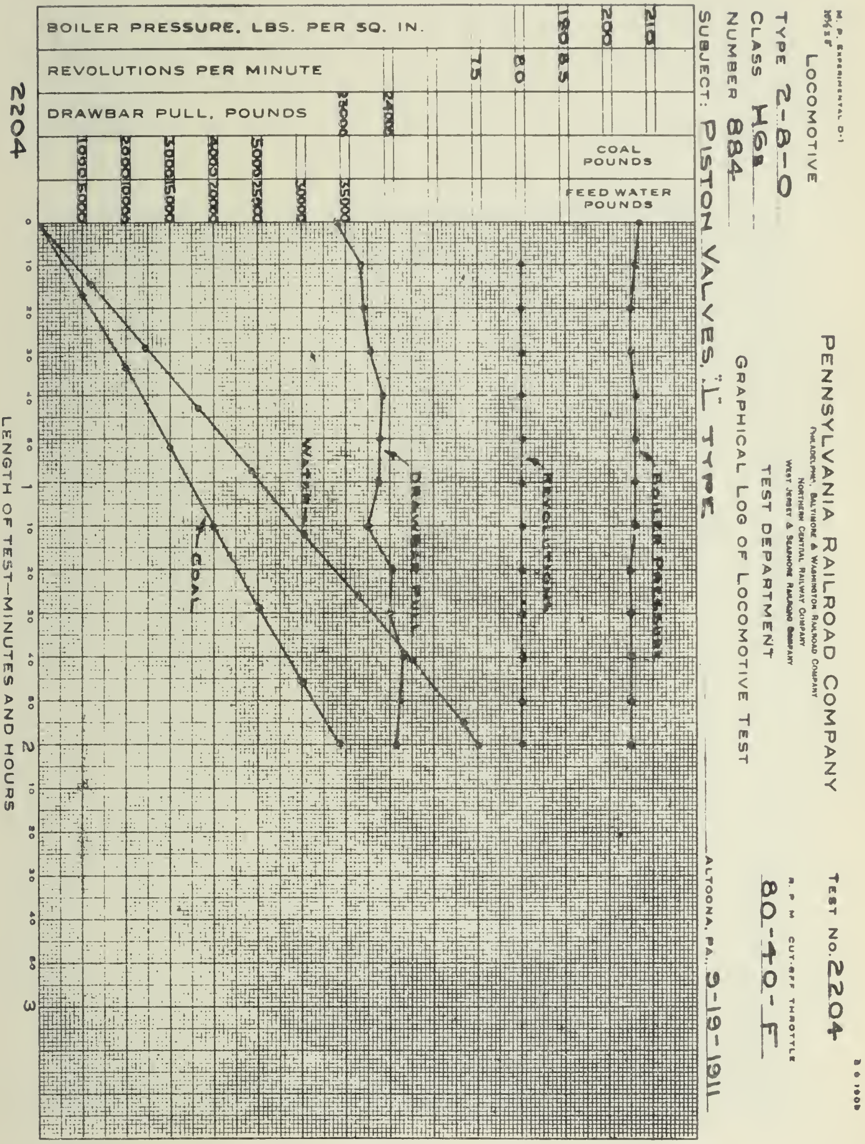

LOCOMOTIVE
TYPE 2-8-0
CLASS H6B
NUMBER 2860
SUBJECT: PISTON VALVES, AMERICAN SEMI-PLUG
PENNSYLVANIA RAILROAD COMPANY
TEST DEPARTMENT
GRAPHICAL LOG OF LOCOMOTIVE TEST
TEST No. 1200.576
R. P. M. CUT-OFF THROTTLE
140-30-F
ALTOONA, PA., 10-7-1910
BOILER PRESSURE, LBS. PER SQ. IN.
REVOLUTIONS PER MINUTE
DRAWBAR PULL, POUNDS
COAL POUNDS
FEED WATER POUNDS
LENGTH OF TEST—MINUTES AND HOURS
1200.576


LOCOMOTIVE
TYPE 2-8-0
CLASS H6B
NUMBER 2860
SUBJECT PISTON VALVES, AMERICAN SEMI-PLUG
PENNSYLVANIA RAILROAD COMPANY
PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY
TEST DEPARTMENT
GRAPHICAL LOG OF LOCOMOTIVE TEST
TEST NO 1200.577
R P M CUT OFF THROTTLE
160-30-F
ALTOONA, PA. 10-10-1910
BOILER PRESSURE, LBS. PER SQ. IN
REVOLUTIONS PER MINUTE
DRAWBAR PULL, POUNDS
COAL POUNDS
FEED WATER POUNDS
210
200
190
165
160
155
15000
14000
Boiler Pressure
Revolutions
Drawbar Pull
Water
Coal
LENGTH OF TEST—MINUTES AND HOURS
1200.577


PENNSYLVANIA RAILROAD COMPANY
PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY
TEST DEPARTMENT
GRAPHICAL LOG OF LOCOMOTIVE TEST
TEST No. 2201
LOCOMOTIVE
TYPE 2-8-0
CLASS H6B
NUMBER 884
SUBJECT: PISTON VALVES, "L" TYPE
R. P. M. CUT-OFF THROTTLE
40-20-F
ALTOONA, PA., 9-14-1911
BOILER PRESSURE, LBS. PER SQ. IN.
REVOLUTIONS PER MINUTE
DRAWBAR PULL, POUNDS
COAL POUNDS
FEED WATER POUNDS
210
200
190
BOILER PRESSURE
REVOLUTIONS
DRAWBAR PULL
WATER
COAL
LENGTH OF TEST—MINUTES AND HOURS
2201


PENNSYLVANIA RAILROAD COMPANY
PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY
TEST DEPARTMENT
GRAPHICAL LOG OF LOCOMOTIVE TEST
TEST No. 2202
R. P. M. CUT-OFF THROTTLE
60-20-F
LOCOMOTIVE
TYPE 2-8-0
CLASS H6B
NUMBER 884
SUBJECT: PISTON VALVES, "L" TYPE
ALTOONA, PA., 9-15-1911
BOILER PRESSURE, LBS. PER SQ. IN.
REVOLUTIONS PER MINUTE
DRAWBAR PULL, POUNDS
COAL POUNDS
FEED WATER POUNDS
210
200
190
185
60
55
11000
BOILER PRESSURE
REVOLUTIONS
DRAWBAR PULL
WATER
COAL
LENGTH OF TEST—MINUTES AND HOURS
1
2
3
2202


LOCOMOTIVE
TYPE 2-8-0
CLASS H6B
NUMBER 884
SUBJECT: PISTON VALVES, "L" TYPE
PENNSYLVANIA RAILROAD COMPANY
PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY
TEST DEPARTMENT
GRAPHICAL LOG OF LOCOMOTIVE TEST
TEST No. 2203
60-30-F
R.P.M. CUT-OFF THROTTLE
ALTOONA, PA. 9-15-1911
BOILER PRESSURE, LBS. PER SQ. IN.
REVOLUTIONS PER MINUTE
DRAWBAR PULL, POUNDS
COAL POUNDS
FEED WATER POUNDS
BOILER PRESSURE
REVOLUTIONS
DRAWBAR PULL
WATER
COAL
2203
LENGTH OF TEST—MINUTES AND HOURS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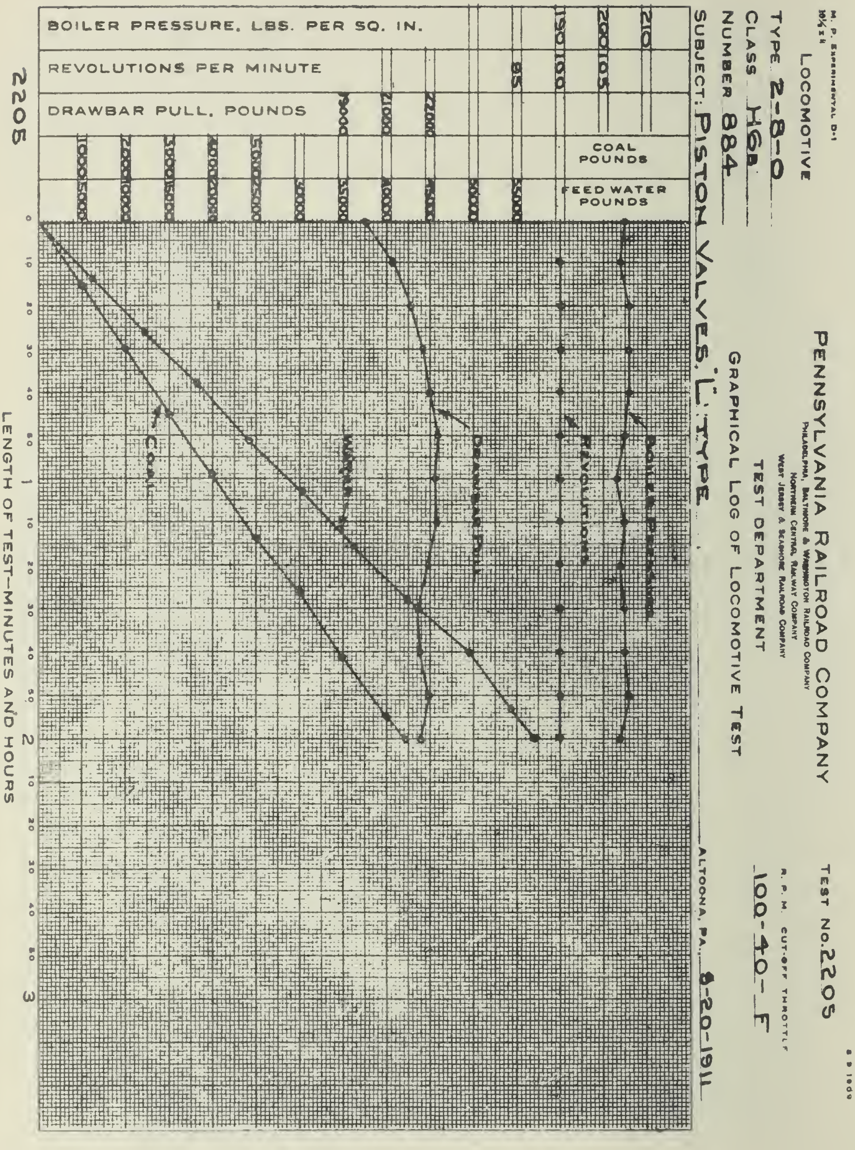
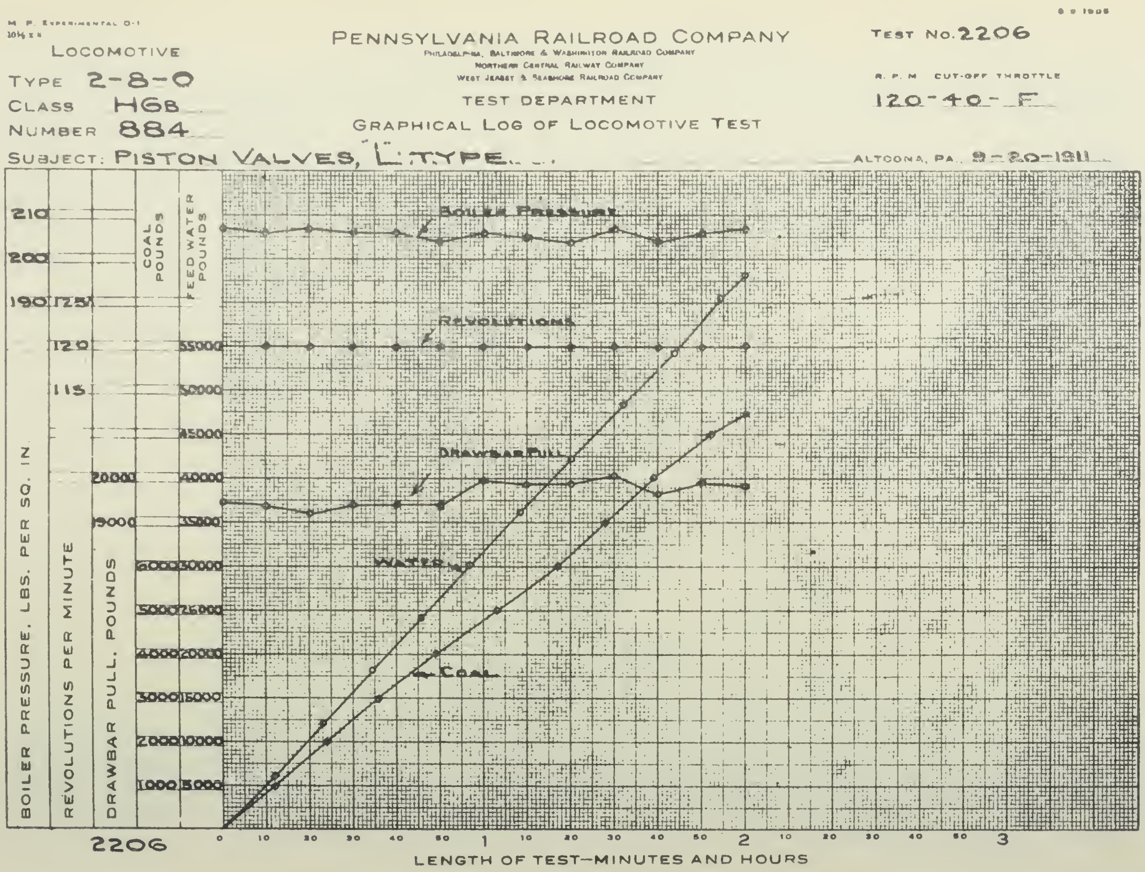
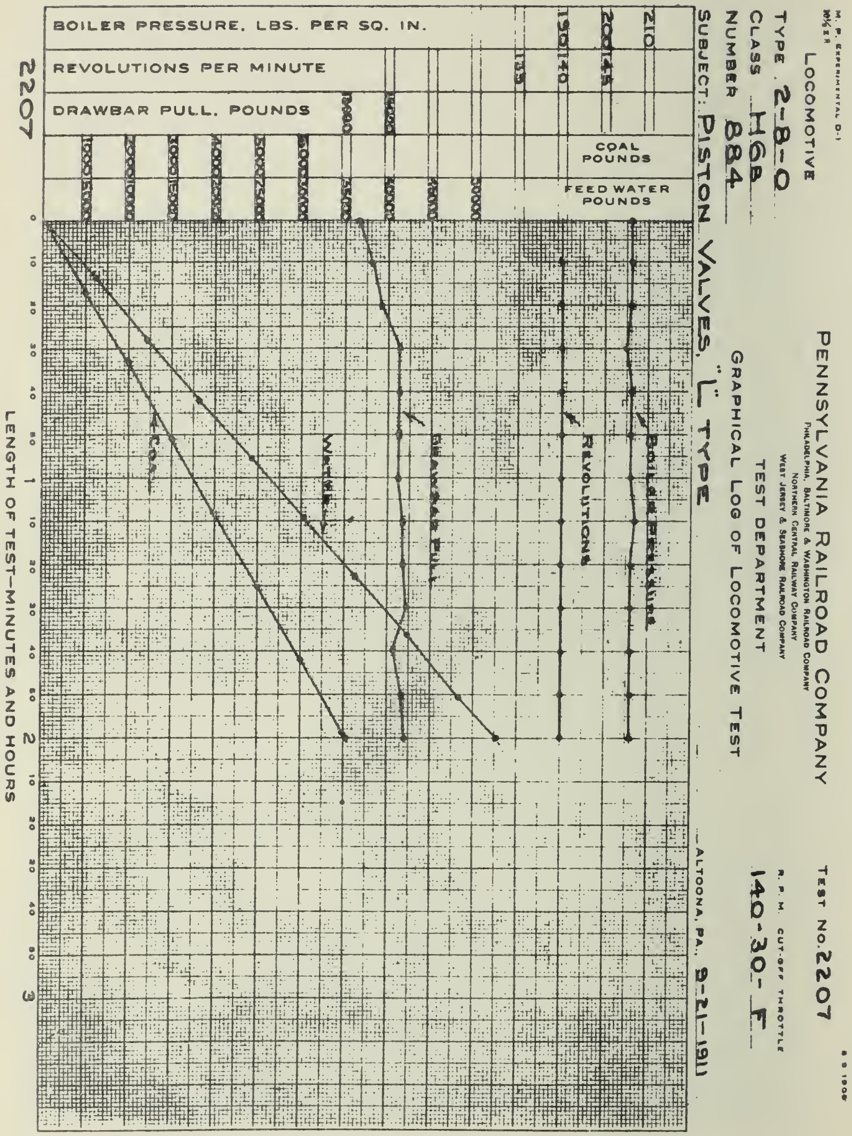
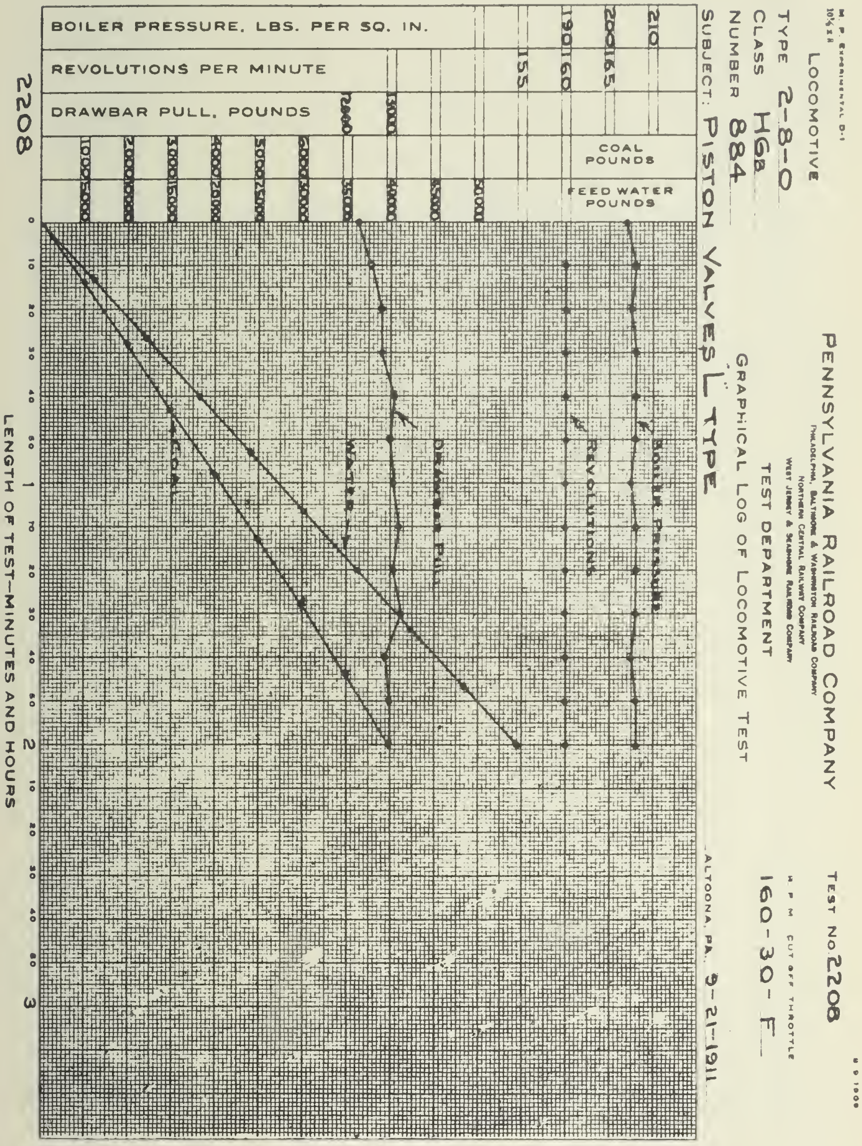
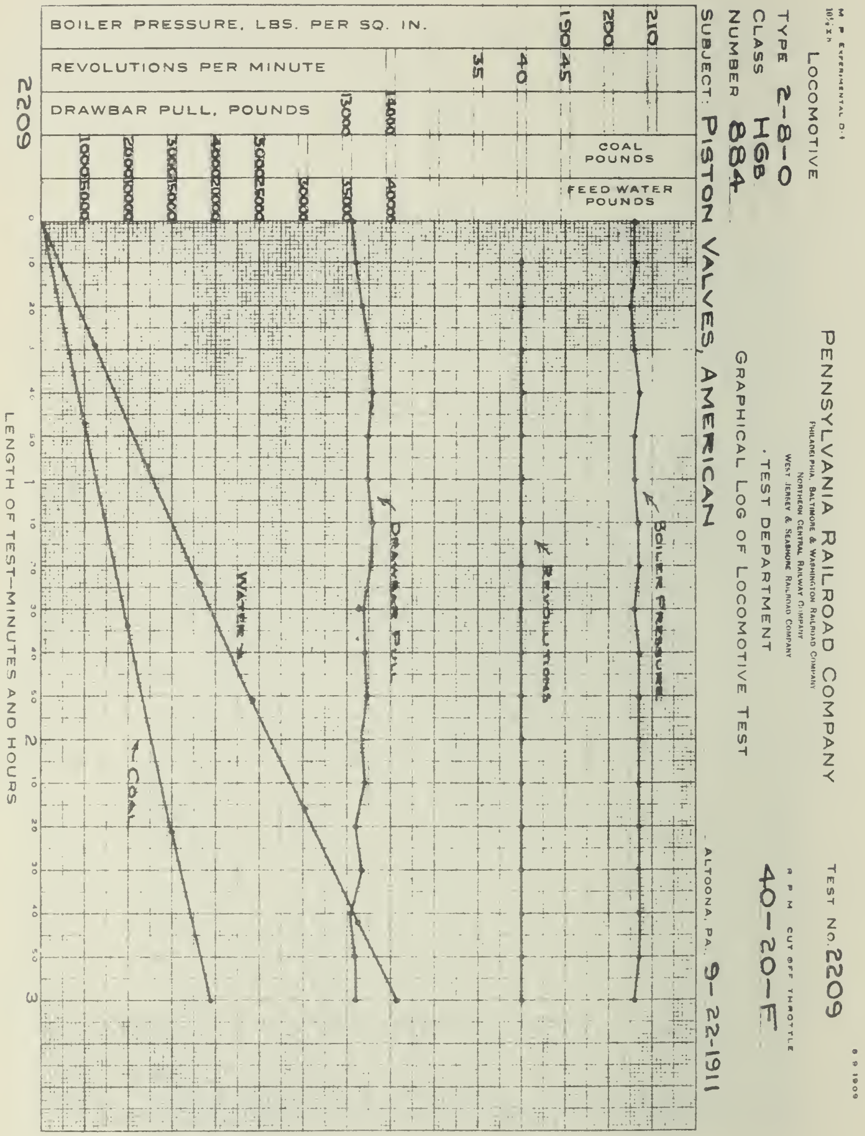
GRAPHICAL LOG OF LOCOMOTIVE TEST
TEST DEPARTMENT
TEST No. 2204
80-40-F
ALTOONA, PA. 9-19-1911
LOCOMOTIVE
TYPE 2-8-0
CLASS H6B
NUMBER 884
SUBJECT: PISTON VALVES, "L" TYPE
BOILER PRESSURE, LBS. PER SQ. IN.
REVOLUTIONS PER MINUTE
DRAWBAR PULL, POUNDS
COAL POUNDS
FEED WATER POUNDS
BOILER PRESSURE
REVOLUTIONS
DRAWBAR PULL
WATER
COAL
LENGTH OF TEST—MINUTES AND HOURS
2204

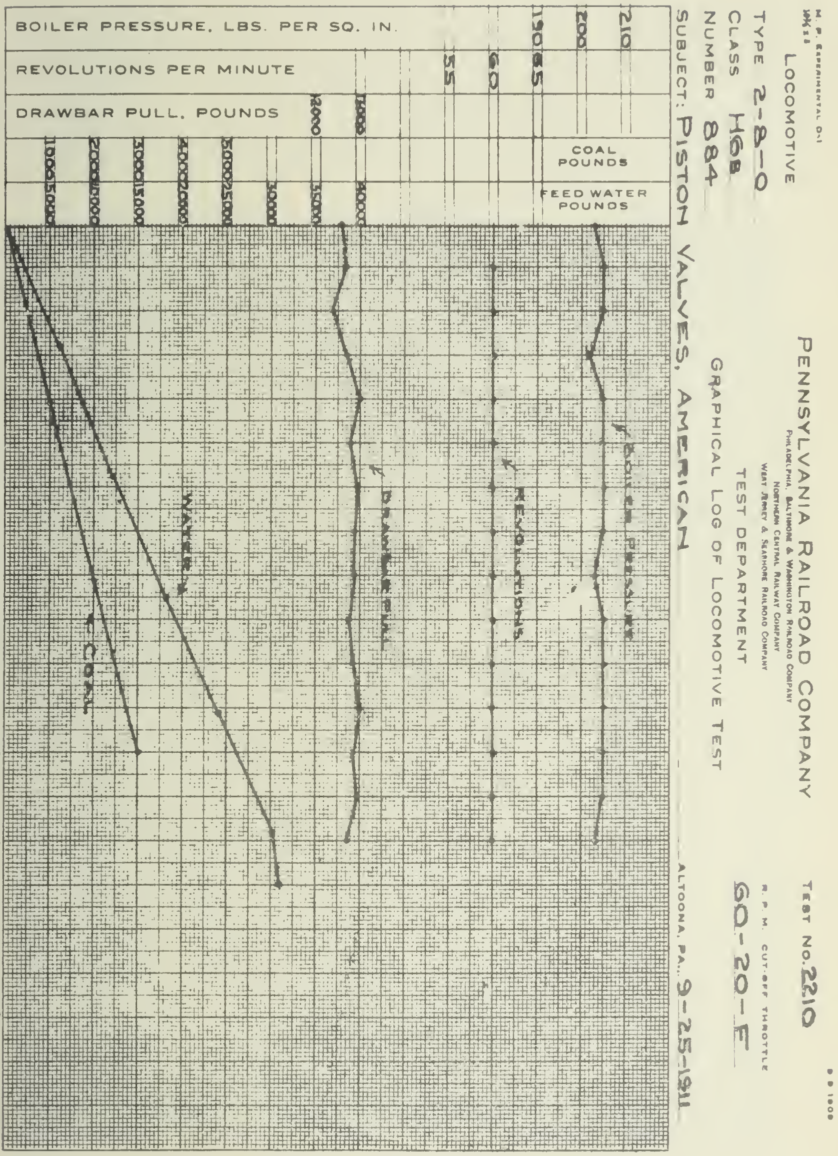

PENNSYLVANIA RAILROAD COMPANY
TEST DEPARTMENT
GRAPHICAL LOG OF LOCOMOTIVE TEST
LOCOMOTIVE
TYPE 2-8-0
CLASS H6B
NUMBER 884
SUBJECT: PISTON VALVES, "L" TYPE
TEST No. 2205
R. P. M. CUT-OFF THROTTLE
100-40-F
ALTOONA, PA., 8-20-1911
BOILER PRESSURE, LBS. PER SQ. IN.
REVOLUTIONS PER MINUTE
DRAWBAR PULL, POUNDS
COAL POUNDS
FEED WATER POUNDS
BOILER PRESSURE
REVOLUTIONS
DRAWBAR PULL
WATER
COAL
LENGTH OF TEST—MINUTES AND HOURS
2205


M. P. Experimental D-1
Locomotive
Type 2-8-0
Class HGB
Number 884
Pennsylvania Railroad Company
Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company
Test Department
Graphical Log of Locomotive Test
Test No. 2206
R. P. M. Cut-off Throttle
120-40-F
Subject: Piston Valves, "L" Type
Altoona, Pa. 9-20-1911
Boiler Pressure, lbs. per sq. in.
Revolutions per minute
Drawbar Pull, pounds
Coal pounds
Feed water pounds
210
200
190
125
120
115
20000
19000
6000
5000
4000
3000
2000
1000
55000
50000
45000
40000
35000
30000
25000
20000
15000
10000
5000
Boiler Pressure
Revolutions
Drawbar Pull
Water
Coal
2206
0
10
20
30
40
50
1
2
3
Length of Test—Minutes and Hours


PENNSYLVANIA RAILROAD COMPANY
PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY
TEST DEPARTMENT
GRAPHICAL LOG OF LOCOMOTIVE TEST
LOCOMOTIVE
TYPE 2-8-0
CLASS H6B
NUMBER 884
SUBJECT: PISTON VALVES, "L" TYPE
TEST No. 2207
R. P. M. CUT-OFF THROTTLE
140-30-F
ALTOONA, PA. 9-21-1911
BOILER PRESSURE, LBS. PER SQ. IN.
REVOLUTIONS PER MINUTE
DRAWBAR PULL, POUNDS
COAL POUNDS
FEED WATER POUNDS
210
200
190
145
140
135
Boiler Pressure
Revolutions
Drawbar Pull
Water
Coal
LENGTH OF TEST—MINUTES AND HOURS
2207


PENNSYLVANIA RAILROAD COMPANY
Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company
TEST No. 2208
LOCOMOTIVE
TYPE 2-8-0
CLASS H6B
NUMBER 884
TEST DEPARTMENT
GRAPHICAL LOG OF LOCOMOTIVE TEST
M P M CUT OFF THROTTLE
160-30-F
SUBJECT: PISTON VALVES "L" TYPE
ALTOONA, PA. 9-21-1911
BOILER PRESSURE, LBS. PER SQ. IN.
REVOLUTIONS PER MINUTE
DRAWBAR PULL, POUNDS
COAL POUNDS
FEED WATER POUNDS
Boiler Pressure
Revolutions
Drawbar Pull
Water
Coal
LENGTH OF TEST—MINUTES AND HOURS
2208


LOCOMOTIVE
TYPE 2-8-0
CLASS H6B
NUMBER 884
SUBJECT: PISTON VALVES, AMERICAN
PENNSYLVANIA RAILROAD COMPANY
PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY
TEST DEPARTMENT
GRAPHICAL LOG OF LOCOMOTIVE TEST
TEST No. 2209
R P M CUT OFF THROTTLE
40-20-F
ALTOONA, PA. 9-22-1911
BOILER PRESSURE, LBS. PER SQ. IN.
210
200
190
REVOLUTIONS PER MINUTE
45
40
35
DRAWBAR PULL, POUNDS
14000
13000
COAL POUNDS
1000
2000
3000
4000
5000
6000
7000
FEED WATER POUNDS
5000
10000
15000
20000
25000
30000
35000
40000
BOILER PRESSURE
REVOLUTIONS
DRAWBAR PULL
WATER
COAL
LENGTH OF TEST—MINUTES AND HOURS
0
10
20
40
50
1
10
20
30
40
50
2
10
20
30
40
50
3
2209


M. P. Experimental 0-1
Pennsylvania Railroad Company
Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company
Test No. 2210
Test Department
Graphical Log of Locomotive Test
R. P. M. Cut-off Throttle
60-20-F
Locomotive
Type 2-8-0
Class H6B
Number 884
Subject: Piston Valves, American
Altoona, Pa., 9-25-1911
Boiler Pressure, Lbs. per Sq. In.
Revolutions per Minute
Drawbar Pull, Pounds
Coal Pounds
Feed Water Pounds
210
200
190
185
60
55
2000
1800
Boiler Pressure
Revolutions
Drawbar Pull
Water
Coal
Length of Test—Minutes and Hours
2210

PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

TEST DEPARTMENT

GRAPHICAL LOG OF LOCOMOTIVE TEST

LOCOMOTIVE

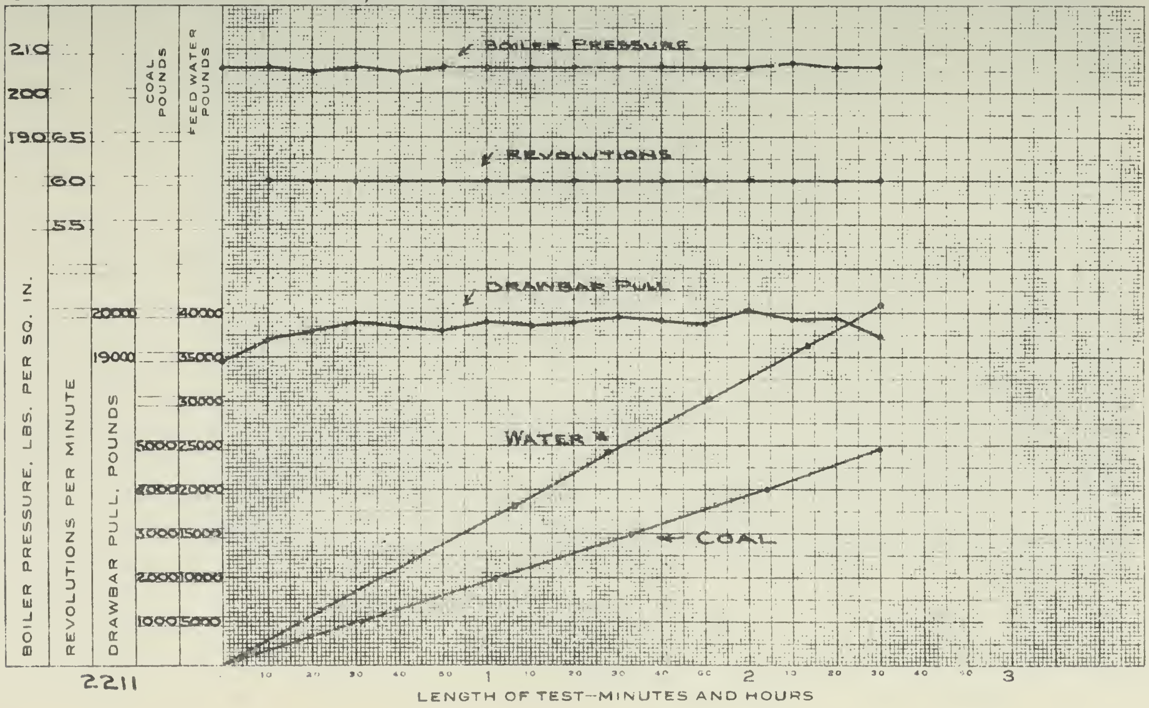
TYPE 2-8-0
CLASS H6B
NUMBER 884

TEST No. 2211

R. P. M. CUT-OFF THROTTLE
60-30-F

SUBJECT: PISTON VALVES, AMERICAN.

ALTOONA, PA., 9-23-1911



2211

M. P. EXPERIMENTAL D-1
10⅝ x H

8-9-1908

LOCOMOTIVE

TYPE 2-8-0
CLASS H6B
NUMBER 884

PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

TEST DEPARTMENT

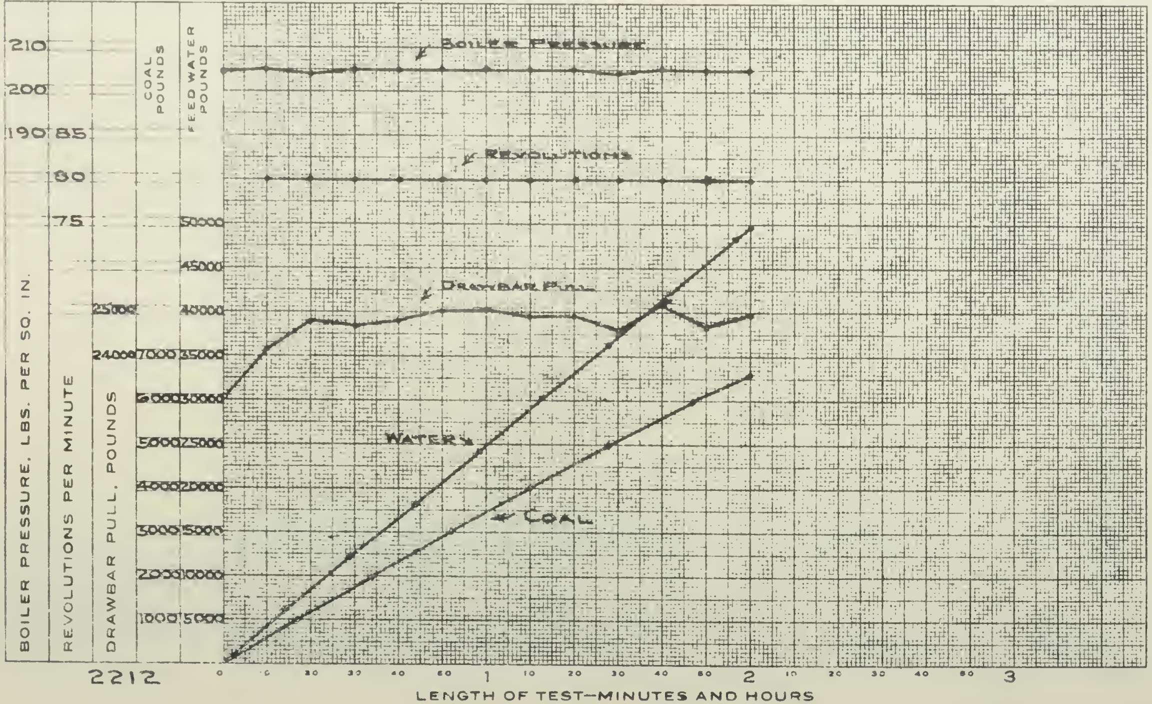
GRAPHICAL LOG OF LOCOMOTIVE TEST

TEST NO. 2212

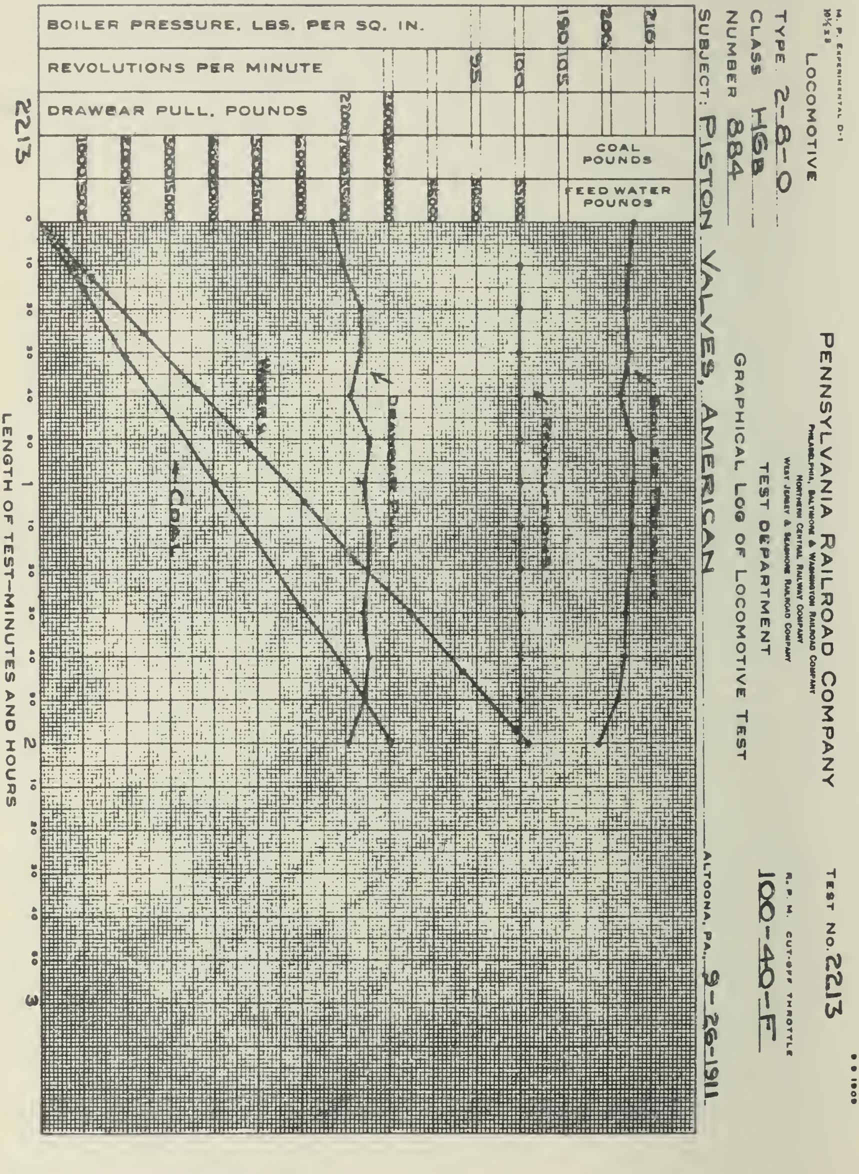
R. P. M. CUT-OFF THROTTLE
80-40-F

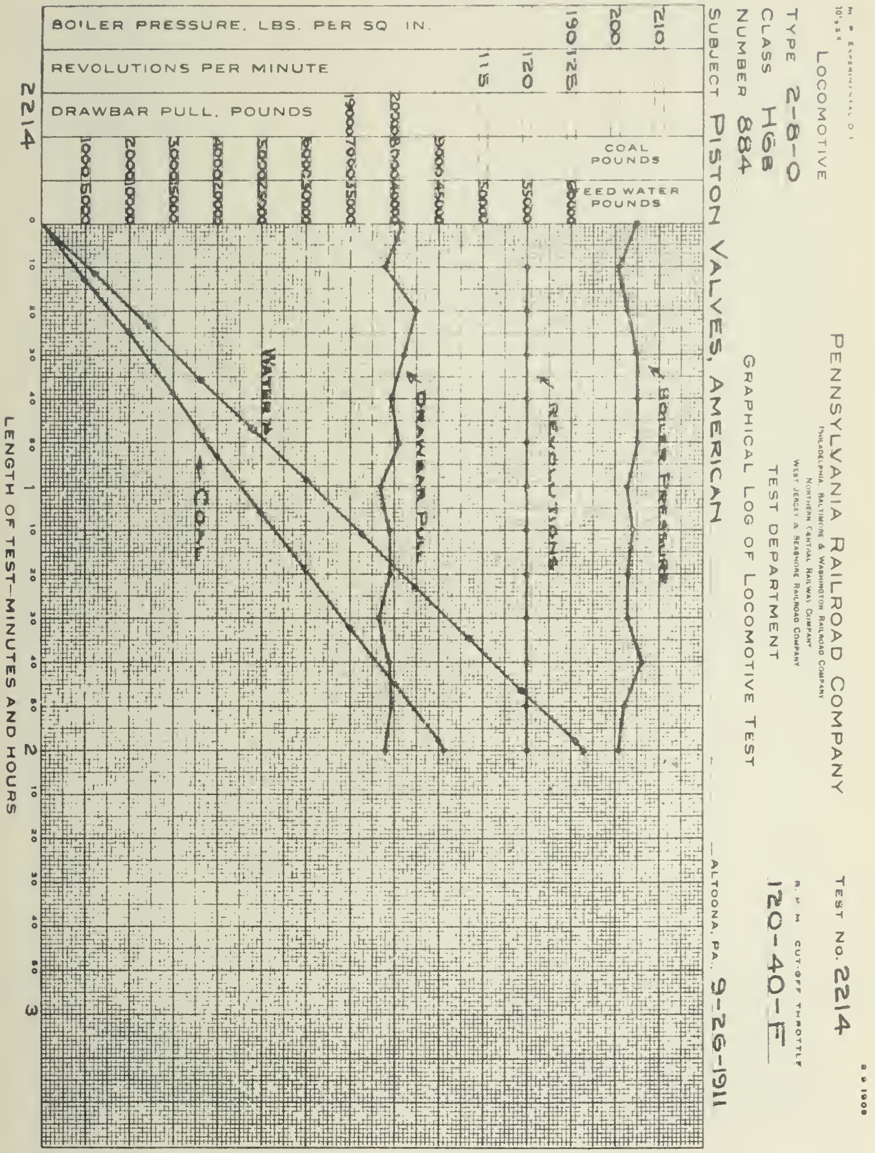
SUBJECT: PISTON VALVES, AMERICAN

ALTOONA, PA., 9-25-1911

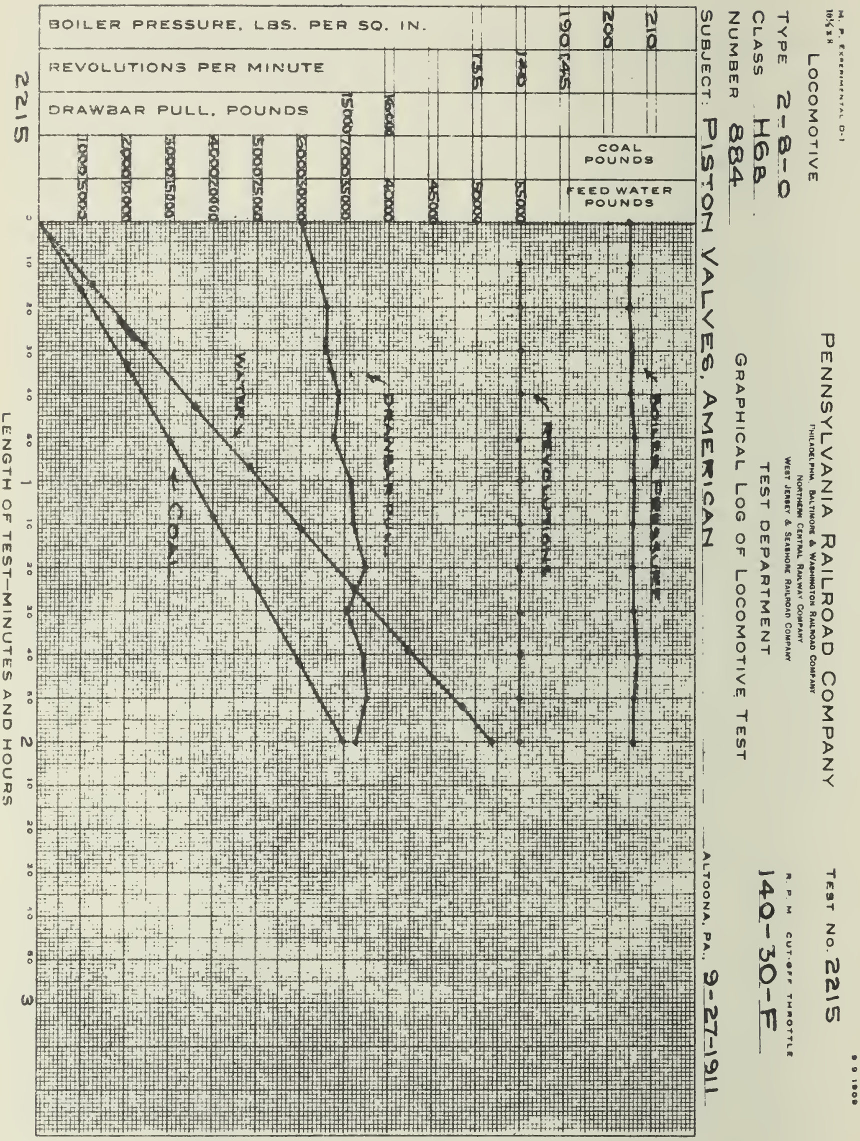


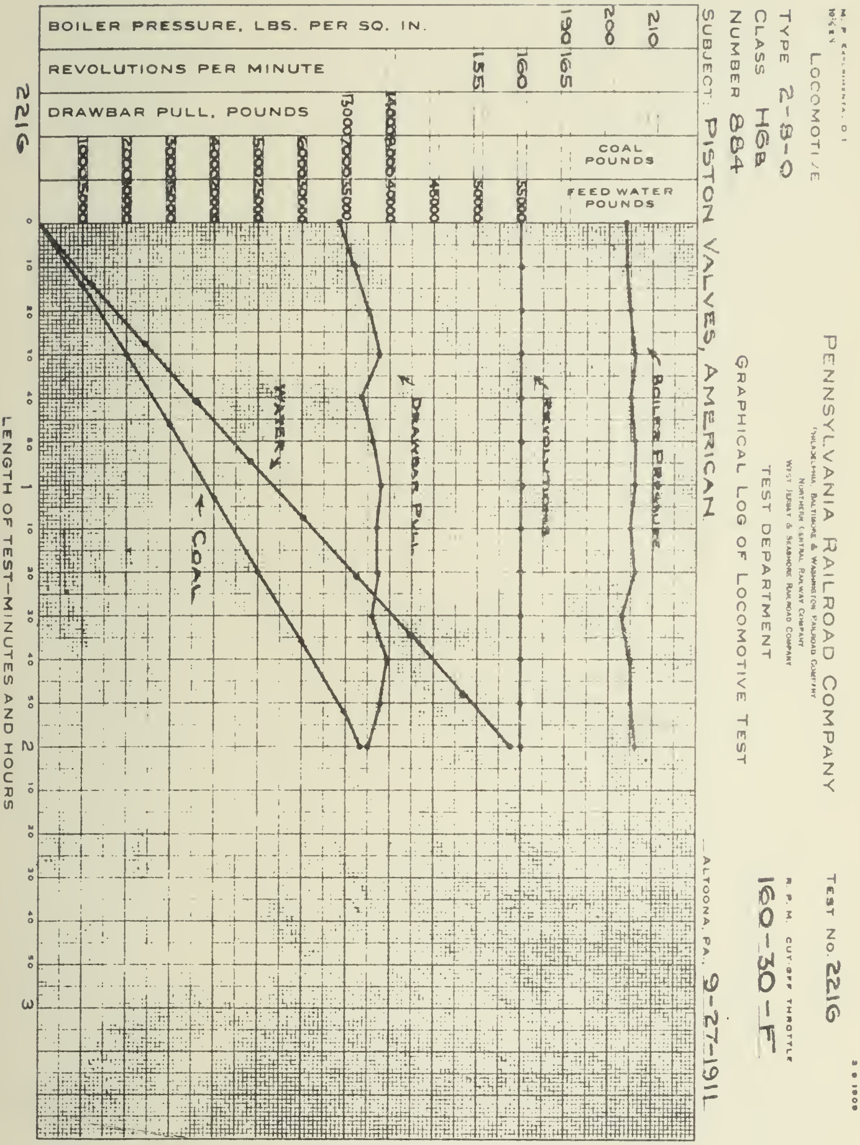
2212


M. P. Experimental D-1
Locomotive
Type 2-8-0
Class H6B
Number 884
Subject: Piston Valves, American
Pennsylvania Railroad Company
Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company
Graphical Log of Locomotive Test
Test Department
Test No. 2213
100-40-F
R. P. M. Cut-off Throttle
Altoona, Pa., 9-26-1911
Boiler Pressure, Lbs. per sq. in.
Revolutions per Minute
Drawbar Pull, Pounds
Coal Pounds
Feed Water Pounds
2213
Length of Test—Minutes and Hours
Drawbar Pull
Revolutions
Boiler Pressure
Water
Coal



Pennsylvania Railroad Company
Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company
Test Department
Graphical Log of Locomotive Test
Test No. 2214
R. P. M. Cut-off Throttle
120-40-F
Locomotive
Type 2-8-0
Class H6b
Number 884
Subject Piston Valves, American
Altoona, Pa., 9-26-1911
Boiler Pressure, Lbs. per Sq. In.
Revolutions per Minute
Drawbar Pull, Pounds
Coal Pounds
Feed Water Pounds
Boiler Pressure
Revolutions
Drawbar Pull
Water
Coal
Length of Test—Minutes and Hours
2214


LOCOMOTIVE
TYPE 2-8-0
CLASS H6B
NUMBER 884
SUBJECT: PISTON VALVES, AMERICAN
PENNSYLVANIA RAILROAD COMPANY
TEST DEPARTMENT
GRAPHICAL LOG OF LOCOMOTIVE TEST
TEST NO. 2215
R. P. M. CUT-OFF THROTTLE
140-30-F
ALTOONA, PA., 9-27-1911
BOILER PRESSURE, LBS. PER SQ. IN.
REVOLUTIONS PER MINUTE
DRAWBAR PULL, POUNDS
COAL POUNDS
FEED WATER POUNDS
BOILER PRESSURE
REVOLUTIONS
DRAWBAR PULL
WATER
COAL
LENGTH OF TEST—MINUTES AND HOURS
2215


PENNSYLVANIA RAILROAD COMPANY
TEST DEPARTMENT
GRAPHICAL LOG OF LOCOMOTIVE TEST
TEST NO. 2216
R. P. M. CUT-OFF THROTTLE
160-30-F
LOCOMOTIVE
TYPE 2-8-0
CLASS H6B
NUMBER 884
SUBJECT: PISTON VALVES, AMERICAN.
ALTOONA, PA. 9-27-1911
BOILER PRESSURE, LBS. PER SQ. IN.
REVOLUTIONS PER MINUTE
DRAWBAR PULL, POUNDS
COAL POUNDS
FEED WATER POUNDS
BOILER PRESSURE
REVOLUTIONS
DRAWBAR PULL
WATER
COAL
LENGTH OF TEST-MINUTES AND HOURS
2216

PENNSYLVANIA RAILROAD COMPANY

Locomotive Testing Plant

AT

ALTOONA, PENNA.

BULLETIN No. 8 (REVISED)

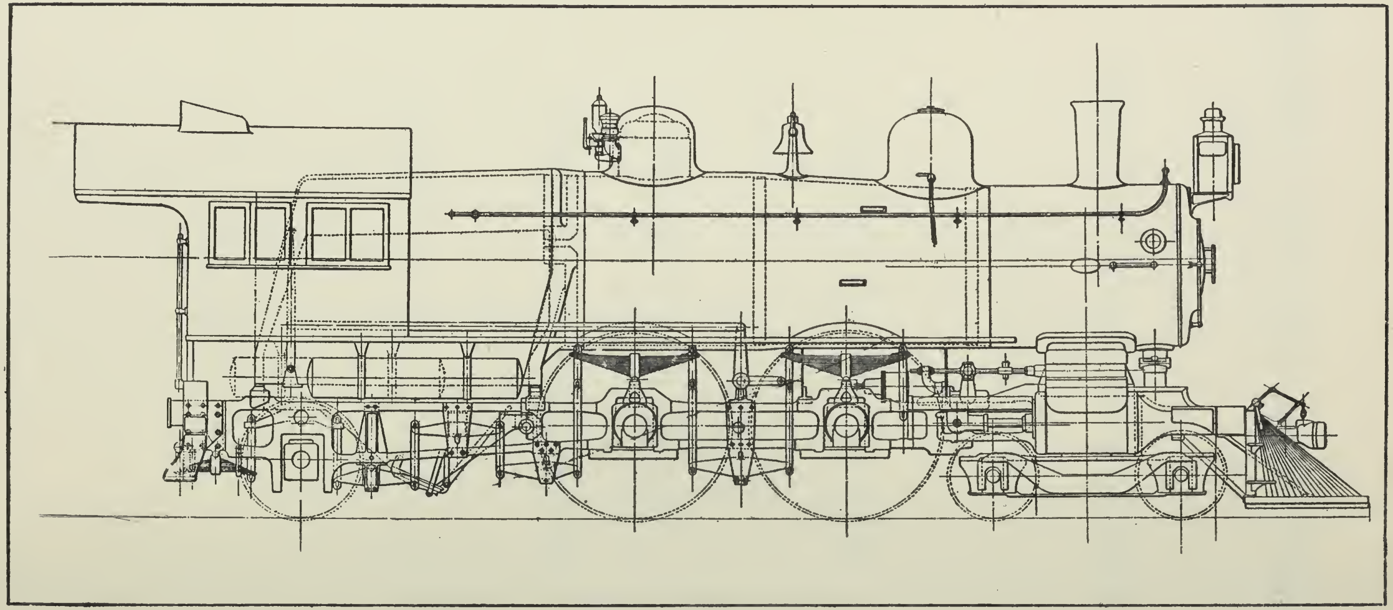
Formerly Bulletins Nos. 10 and 23

GRATE AREA REDUCED

AND

GRATES WITH SOLID ENDS

1912



GENERAL ARRANGEMENT OF LOCOMOTIVE.
Fig. 1.

LOCOMOTIVE TESTING PLANT.

GRATE AREA REDUCED.

Two forms of modified grate tested for their influence upon boiler efficiency and smoke.

(Conclusions and recommendations on pages 26 and 29.)

INTRODUCTION.

1. These tests justify the conclusion that a reduction in the grate area is undesirable and that such a practice affects the boiler capacity and efficiency and does not improve the smoke conditions. Efforts to abate smoke on a locomotive should be directed along other lines than by the blocking off of existing grate areas.

2. In view of the introduction of mechanical stokers, the subject deserves more careful study, and it is hoped that the following description of tests of different areas of grate will add something of value to the data on this subject.

3. Before the general use of the wide grate on locomotives, the length had been limited to about ten feet, as the greatest distance that coal could be thrown by the average fireman and with the introduction of the wide grate the length has still been restricted for the same reason.

4. There seems to be an impression on certain divisions that the wide grate is too large on some of our passenger locomotives, for best results, and extensive use has been made of a method of blocking off or covering part of the grate surface, usually at the forward end. The assertions in regard to this or any other method of reducing the grate area were debatable. On long passenger runs it has been claimed that the grate, thus reduced in area, is easier to fire because of its being smaller and the active part near the firedoor so that coal does not have to be thrown so far to cover it.

5. Whether or not the reduced grate is easier for the fireman to handle will probably remain a matter of individual opinion and one not easily determined for the average fireman. There are, however, certain facts in regard to the reduced grate that can be developed by tests, and the tests hereafter described have been made to show the effect of the reduced grate, in coal consumption and emission of smoke. The practice of reducing the grate is found to be undesirable as the capacity of the locomotive for making steam is reduced and little benefit in smoke reduction realized.

6. The standard grate for the class E2a locomotive has an area of 55.5 square feet, including the dead grate at the forward end, which has an area of about 9 square feet. There are two drop grates which are fixed, but have holes for the admission of air. The active or shaking portion of the grate has an area of about 31 square feet.

Method of Reducing Grate Area.

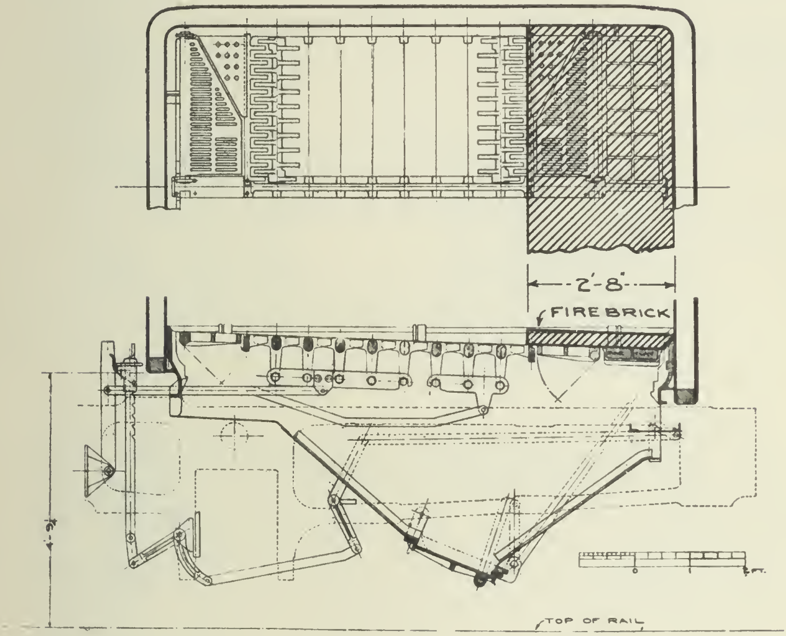
7. On the Atlantic City Division where the grate has been reduced, the method used is to disconnect six sections of shaking grate at the front end of the firebox. This portion of the grate is then covered with firebrick. Sometimes a sheet of steel is placed over the grate before laying the bricks so that there will be no cold air leaks, should any of the bricks become broken.

8. On the New Jersey Division a similar method is used but the area covered with brick is less, so that all of the shaking part of the grate is still open and can be operated.

9. The areas of the several grates are given below.

	Area of Grate in Sq. Feet.	Relative Area in Percent.	Ratio of Heating Surface to Grate Area.
Standard	55.5	100	41.8
New Jersey Division	39.5	71	58.7
Atlantic City Division	29.76	54	77.9

10. The grate of this locomotive as reduced in area on the New Jersey Division is shown in Fig. 2, while Fig. 3 shows the method used on the Atlantic City Division.



GRATE WITH FRONT PORTION COVERED WITH FIREBRICK
as used on New Jersey Division. All of the shaking grates can be used. The grate area is reduced 29%.
Fig. 2.

11. The locomotive used in the tests was an Atlantic Type passenger locomotive of the E2a class and is shown in Fig. 1.

Coal Used in the Tests.

12. Two kinds of coal were tried, one a low volatile coal, which breaks up easily into small particles and is drawn through the tubes in the form of cinders and sparks, and the other a

Pittsburgh region gas coal, which shows little tendency to disintegrate in the firebox. The analysis of the two coals was as follows:

	Scalp Level Coal	Penn Gas Coal
Fixed carbon	76.98%	58.35%
Volatile combustible	15.96	35.65
Ash	6.02	4.71
Moisture	1.04	1.29
	100.00	100.00
Sulphur	0.91	1.15
B. t. u. per pound, dry	15167	14864

Method of Making Tests.

13. The tests were of two or three hours duration in most cases. The locomotive was run under the test conditions for about fifteen minutes before the test began. The fire would then have been built up and the rate of firing established for the load upon the boiler. The firing was continued at the same rate of firing as shown by the graphical log for each test.

14. The boiler was operated under light, medium, and heavy loads and the firing was done by experienced men.

Results of Tests.

Low Volatile Coal, Evaporation:

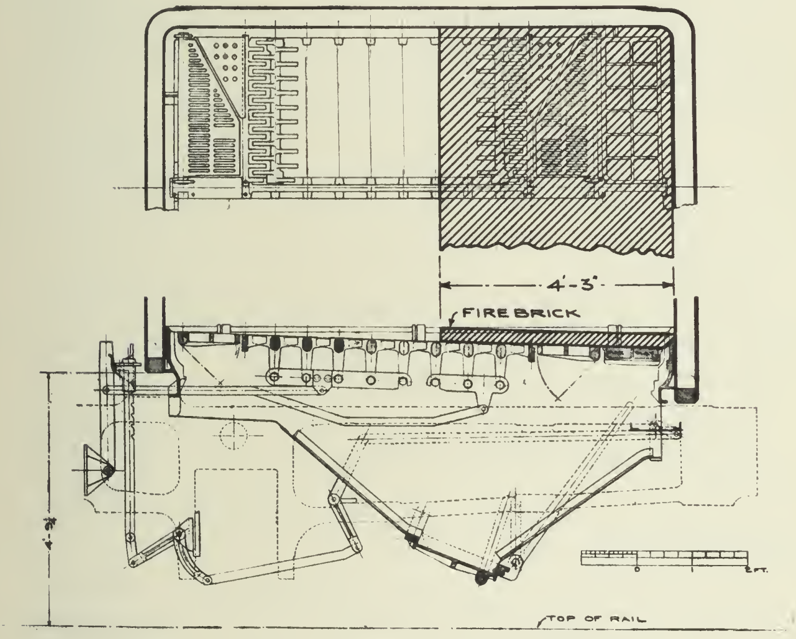
15. The results of the tests with the low volatile coal on two sizes of grate are shown on Tables 4 and 6 and some of these results, showing the evaporation and efficiency, are plotted in Figs. 4, 5 and 6.

16. With the reduced grate there is a loss in evaporation and efficiency through the whole range of out-put of the boiler; the

greatest loss being shown at the lower rates of evaporation.

17. When the boiler is evaporating water at the rate of about 14 pounds per square foot of heating surface, the loss in coal due to the use of the small grate is about 29.4 per cent.

18. With the small grate the boiler could be forced to an evaporation of about 14 pounds per square foot of heating sur-



GRATE WITH FRONT PORTION COVERED WITH FIREBRICK
as used on Atlantic City Division. Six grate bars are inoperative. The grate area is reduced 46%.
Fig. 3.

face, while with the full size grate in use the evaporation was 16 pounds per square foot of heating surface, or an increase of 14.3 per cent. The small grate then limits the steaming capacity of the boiler.

19. The use of the low volatile coal, such as was tried in this test, is not present practice on passenger locomotives, and the tests show very clearly that this small grate is not at all suitable for this class of coal.

Cinders and Sparks:

20. The immediate effect of a reduction in grate area with low volatile coal is to cause more cinders and sparks to be drawn through the tubes, for the reason that, as the area of the grate becomes smaller, the draft, through what is left, becomes more intense and as a consequence the particles of coal are carried along with the gases in increasing quantities. These unburned cinders and sparks are almost entirely clean coke, and would, if burned, release about ten or eleven thousand heat units per pound. They escape unburned, however, and the heat that they contain is lost. The disadvantage of increasing the spark and cinder losses is thus apparent, because it means a loss of heat that might be made available for evaporation.

21. An indication of the extent of the losses from the cinders and sparks is given in Table 1 where the calorific value of the coal is compared with that of the cinders collected in the smoke-box and the sparks discharged from the stack.

22. With low volatile coal the cinders collected in the smoke-box were at times as much as 900 pounds per hour, with the full grate, and it is evident that even the full grate is not large enough, and only allows this coal to be burned with serious cinder and spark losses.

23. The weight of the sparks thrown out of the stack was not observed, as a satisfactory method for catching them had not yet been provided at the time of the tests. These sparks are large in amount, however, and their discharge from the stack is undesirable as in the course of time they fill the stone ballast of the track and choke the drainage making it necessary to frequently fork the ballast in order to keep the road bed in proper condition.

High Volatile Coal, Evaporation:

24. Following those already described, another series of

M. P. 894A
8 x 10½

7 6 1907

PENNSYLVANIA RAILROAD COMPANY

Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company

TEST DEPARTMENT

AVERAGE RESULTS OF LOCOMOTIVE TESTS

LOCOMOTIVE:
TYPE 4-4-2
CLASS E2a
NUMBER 5266

Bulletin No. 8
TEST NOS., 950 to 953.
901,908,916,917,918.

SUBJECT: Grate Area Reducod.

ALTOONA, PA., 8-10-1907

	DRIVING WHEELS	
1	Number of Pairs	2
2	Approx. Diameter, inches	80
	ENGINE TRUCK WHEELS	
14	Number	4
15	Diameter, inches	36
	TRAILING WHEELS	
16	Diameter, inches	50
	WHEEL BASE, FEET	
17	Driving Wheel Base	7.42
18	Total Wheel Base	30.85
19	Gage of Wheels, in.	56.13
	WEIGHT OF ENGINE WITH WATER AT 2D. GAGE COCK AND NORMAL FIRE, POUNDS	
20	On Truck	37167
21	" 1st Drivers	53334
22	" 2d "	56667
23	" 3d "	—
24	" 4th "	—
25	" 5th "	—
26	" Trailers	37000
27	Total	184167
28	" on Drivers	110000
	CYLINDERS	
	Diam. and Stroke, H. P	20.5 x 26
	" " " L. P	—
	CLEARANCE IN PER CENT. OF PISTON DISPLACEMENT	
40	H. P. Right, Head End	12.7
41	" " Crank "	12.1
42	" Left, Head "	12.4
43	" " Crank "	11.9
44	L. P. Right, Head "	—
45	" " Crank "	—
46	" Left, Head "	—
47	" " Crank "	—
	RECEIVER, CUBIC FEET	
48	Volume Right Side	—
49	" Left "	—
	STEAM PORTS, INCHES	
50	H. P. Admission, Length	19.87
51	" " Width	1.48
58	L. P. " Length	—
59	" " Width	—
66	H. P. Exhaust, Length	19.84
67	" " Width	2.98
70	L. P. " Length	—
71	" " Width	—

	PISTON RODS, DIAMETER INCHES	
74	High Pressure	3.472
76	Low "	—
	TAIL RODS, DIAMETER, INCHES	
78	High Pressure	—
80	Low "	—
	VALVES	slido
82	Type	Doublo Portod Bal.
83	Design	Amer. Bal. Valvo Co.
84	Per Cent. Balanced	75.7
85	Type of Valve Motion	Stephenson
	GREATEST VALVE TRAVEL	
86	High Pressure, inches	7.0
88	Low " "	—
	OUTSIDE LAP OF VALVE	
90	High Pressure, inches	1.5
94	Low " "	—
	INSIDE LAP OF VALVE	
98	High Pressure, inches	Neg. 0.16
102	Low " "	—
	BOILER	
113	Type	Belpaire, wide firebox
114	Outside Diam. 1st Ring	67
	TUBES	
115	Number	315
116	Outside Diam., inches	2
	Pitch "	2.625
118	Length Between Tube Sheets, inches	179.78
119	Total Fire Area, sq. ft.	5.26
124	Boiler Pressure, pounds	205
	SUPERHEATER	
125	Number of Tubes	—
126	Outside Diam. " inches	—
128	Length of " "	—
	FIREBOX, INSIDE, INCHES	
132	Length	114
133	Width	68
137	Air Inlets to Ashpan, sq. ft.	6.3
	GRATES	
144	Type	Rocking Finger
145	Grate Area, sq. ft.	55.5
146	Area of Dead Grates	6.0

	HEATING SURFACE, SQUARE FEET	
154	Of the Tubes, Water Side	2471.04
155	" " " Fire "	2162.40
156	" " Firebox, " "	156.86
157	" " Superh'r, " "	—
*158	Total, Based on " "	2319.26
159	" " " " " of Firebox and Water Side of Tubes	2627.90
	BOILER VOLUME WITH WATER SURFACE AT LEVEL OF 2D GAGE COCK	
160	Water Space, cu. ft.	338.6
161	Steam " " "	109.9
	EXHAUST NOZZLE	
162	Double or Single	Single
163	Size, inches	5.625
167	Area, sq. inches	24.85
	REVERSE LEVER	
168	H. P. Notches Forward of Center	15
169	L. P. Notches Forward of Center	—
	RATIOS Full Grate	
171	Heating Surface (158) to Grate Area (145)	41.79
172	Fire Area Thru Tubes (119) to Grate Area (145)	0.09
173	Firebox Heating Surface (156) to Grate Area (145)	2.83
174	Tube Heating Surface (155) to Fire Box Heating Surface (156)	13.79

Ratios, Reducod Grato.

	Grate area	39.5	29.76
171	---------	58.71	77.93
172	---------	0.13	0.18
173	---------	3.97	5.27

*USED IN CALCULATIONS

DIMENSIONS OF E2a CLASS LOCOMOTIVE 5266.
The locomotive used for the Reduced Grate tests.
Table 3.

M. P. 394 A—Sixth Sheet
8 x 10½

11-0-10

PENNSYLVANIA RAILROAD COMPANY Bulletin No. 8

Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company

TEST DEPARTMENT

AVERAGE RESULTS OF LOCOMOTIVE TESTS

LOCOMOTIVE:
TYPE 4-4-2
CLASS E2a
NUMBER 5266

950 to 953
FUEL: Penn Gas.
901 to 917
Scalp Level

SUBJECT: Full Grate, 55.5 sq. ft.

ALTOONA, PA., 8-10-07

TEST NUMBER	RUNNING CONDITIONS: TEST DESIGNATION	Duration of Test, Hours	Miles per Hour	Throttle Opening, Full or Partial	Actual Cut-off Per Cent., H. P. Cylinders	Coal	BOILER PERFORMANCE: Pressure in Boiler, Lbs. per Sq. Inch	Draft in Smoke Box, Inches of Water	Draft in Ash Pan, Inches of Water	Calorific Value of Dry Fuel, B. T. U. per Lb.	Cinders Collected in Smoke Box, Pounds per Hour
	R. P. M. Cut-off Throttle	196	199	203	268 to 271		217	222	225	248	238
950	80-15-F	3.00	19.10	Full		Penn	204.5	2.0	.1	14713	125
951	120-20-F	3.00	28.42	"		Gas	201.4	3.4	.2	14864	49
952	160-25-F	2.50	38.02	"		"	201.9	3.8	.2	14864	48
953	160-3[illegible]-F	2.00	38.02	"		"	198.9	7.3	.3	14864	91
901	80-15-F	3.00	19.10	"		Scalp	201.3	2.0	.2	15264	52
908	120-20-F	3.00	28.65	"		Level	201.0	3.9	.7	15167	101
916	160-25-F	2.50	38.20	"		"	200.0	5.2	.3	15264	302
917	160-27-F	3.00	38.20	"		"	188.4	7.7	.3	15167	492
918	160-30-F	1.00	38.20	"		"	186.1	8.9	1.3	15167	987

TEST NUMBER	BOILER PERFORMANCE: Dry Fuel Fired per Hour, Pounds	Dry Fuel per Hour, Pounds per Sq. Ft. of Grate	Water Delivered to Boiler, Pounds per Hour	Equivalent Evaporation from and at 212° F., Pounds: Per Hour	Equivalent Evaporation: Per Hour per Sq. Ft. of Fire Heating Sur.	Equivalent Evaporation: Per Pound of Dry Fuel	Boiler Horse Power (34½ U. of E.)	Efficiency of Boiler, Based on Fuel	Draft in Fire-box.	ENGINE PERFORMANCE: Pressure in Branch Pipe, Pounds per Sq. In.	Superheat in Branch Pipe Degrees F.
	338	339	340	344	345	347	349	350		220	230
950	1808	32.58	14647	17798	7.67	9.84	515.9	64.59	0.5		
951	2585	46.58	20652	25235	10.88	9.76	731.4	63.42	0.8		
952	3768	67.89	27598	33764	14.56	8.96	978.7	58.22	1.2		
953	5480	98.74	35144	43030	18.56	7.85	1247.3	51.01	2.1		
901	1665	30.00	14673	17806	7.68	10.69	516.0	67.65	0.6	198.3	
908	2455	44.24	20135	24434	10.54	9.95	708.2	63.36	1.7	197.7	
916	4221	76.05	26436	32246	13.90	7.64	934.7	48.34	1.5	195.0	
917	4802	86.53	28670	34793	15.00	7.25	1008.5	46.17	2.1	185.6	
918	5581	100.58	30721	37170	16.03	6.66	1077.4	42.41	3.0	181.8	

TEST NUMBER	ENGINE PERFORMANCE: Dry Steam to Engines, Pounds per Hour	Indicated Horse Power	Dry Fuel per Indicated Horse Power Hour, Pounds	Dry Steam per Indicated Horse Power Hour, Pounds	C O Smoke-box gases	LOCOMOTIVE PERFORMANCE: Drawbar Pull, Pounds	Dynamometer or Drawbar Horse Power	Dry Fuel per Dynamom. Horse Power Hour, Pounds	Dry Steam per Dynamom. Horse Power Hour, Pounds	Machine Efficiency of Locomotive, Per Cent.	Thermal Efficiency of Locomotive, per Cent., (Based on Fuel)	Smoke in Percent
	214	379	380	381		265	383	384	385	398	399	
950	14172				0	7059	359.6	5.03	39.42		3.44	72
951	20448				0	7579	574.3	4.50	35.58		3.80	38
952	27326				.27	8768	888.9	4.24	30.74		4.04	46
953	34800				.67	11790	1195.3	4.58	29.11		3.74	52
901	14077	419.8	3.97	33.54	0	[illegible]427	327.3	5.09	43.02		3.28	No
908	19548	687.6	3.57	28.81	0	7280	556.2	4.42	35.16		3.79	Record
916	25529	1011.6	4.17	25.23	0.06	8155	830.7	5.08	30.73		3.28	
917	27958	10[illegible]5.0	4.55	26.50	0.60	8757	892.1	5.38	31.34		3.18	
918	30057	1133.4	4.92	26.46	0.60	9571	975.0	5.72	30.83		2.98	

TESTS WITH THE WHOLE GRATE IN USE.
Two coals were used, Penn Gas and Scalp Level. The first a high, and the second a low volatile coal.

Table 4.

M. P. 894 A—Sixth Sheet
8 x 10½

7 6 1907

PENNSYLVANIA RAILROAD COMPANY

Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company

TEST DEPARTMENT

AVERAGE RESULTS OF LOCOMOTIVE TESTS

LOCOMOTIVE:
TYPE 4-4-2
CLASS E2a
NUMBER 5266

Bulletin No. 8
FUEL: Penn Gas Coal

SUBJECT: Grate Area Reduced to 39.5 sq. ft.

ALTOONA, PA., 8-10-07

TEST NUMBER	RUNNING CONDITIONS: TEST DESIGNATION	Duration of Test, Hours	Miles per Hour	Throttle Opening, Full or Partial	Actual Cut-off Per Cent., H. P. Cylinders	Coal	BOILER PERFORMANCE: Pressure in Boiler, Lbs. per Sq. Inch	Draft in Smoke Box, Inches of Water	Draft in Ash Pan, Inches of Water	Calorific Value of Dry Fuel, B.T.U. per Lb.	Cinders Collected in Smoke Box, Pounds per Hour
	R. P. M. Cut-off Throttle	196	199	203	268 to 271		217	222	226	248	238
905	80-15-F	3.00	19.01	Full		Penn	200.7	2.2	.1	14411	26
925	120-20-F	3.00	28.42	"		Gas	204.9	3.5	.3	14411	31
926	160-25-F	2.50	37.78	"			203.1	4.7	.3	14411	81
928	160-32-F	2.00	37.78	"			201.5	7.5	.3	14411	120

TEST NUMBER	BOILER PERFORMANCE: Dry Fuel Fired per Hour, Pounds	Dry Fuel per Hour, Pounds per Sq. Ft. of Grate	Water Delivered to Boiler, Pounds per Hour	Equivalent Evaporation from and at 212° F., Pounds: Per Hour	Per Hour per Sq. Ft. of Fire Heating Sur.	Per Pound of Dry Fuel	Boiler Horse Power (34½ U. of E.)	Efficiency of Boiler, Based on Fuel	Draft in Fire-box.	ENGINE PERFORMANCE: Pressure in Branch Pipe, Pounds per Sq. In.	Superheat in Branch Pipe, Degrees F.
	338	339	340	344	345	347	349	350		220	230
905	1802	45.62	15083	18483	7.97	10.26	535.7	68.76	0.5		
925	25.36	64.20	20097	24395	10.52	9.62	707.1	64.47	1.3		
926	3952	100.05	26558	32285	13.92	8.17	935.8	54.75	1.5		
928	5389	136.43	34350	41802	18.02	7.76	1211.7	52.01	2.7		

TEST NUMBER	ENGINE PERFORMANCE: Dry Steam to Engines, Pounds per Hour	Indicated Horse Power	Dry Fuel per Indicated Horse Power Hour, Pounds	Dry Steam per Indicated Horse Power Hour, Pounds	C O in Smoke-box gases.	LOCOMOTIVE PERFORMANCE: Drawbar Pull, Pounds	Dynamometer or Drawbar Horse Power	Dry Fuel per Dynamom. Horse Power Hour, Pounds	Dry Steam per Dynamom. Horse Power Hour, Pounds	Machine Efficiency of Locomotive, Per Cent.	Thermal Efficiency of Locomotive, per Cent., (Based on Fuel)	Smoke in Percent
	214	379	380	381		265	383	384	385	398	399	
905					0	7454	377.8	4.77	39.48		3.70	18
925					0.07	8072	613.7	4.13	32.40		4.28	24
926					0	9561	963.3	4.10	27.18		4.31	36
928					0.4	11980	1207.0	4.46	28.15		3.96	52

TESTS WITH THE GRATE REDUCED
as in Fig. 2, and using a high volatile coal.
Table 5.

M. P. 394 A—Sixth Sheet
8 x 10½

11-9-10

PENNSYLVANIA RAILROAD COMPANY

Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company

TEST DEPARTMENT

AVERAGE RESULTS OF LOCOMOTIVE TESTS

Bulletin No. 8

LOCOMOTIVE:
TYPE 4-4-2
CLASS E2a
NUMBER 5266

945 to 948
FUEL: Penn Gas
940 to 944
Scalp Level

SUBJECT: Grate Area Reduced to 29.76 sq. ft.

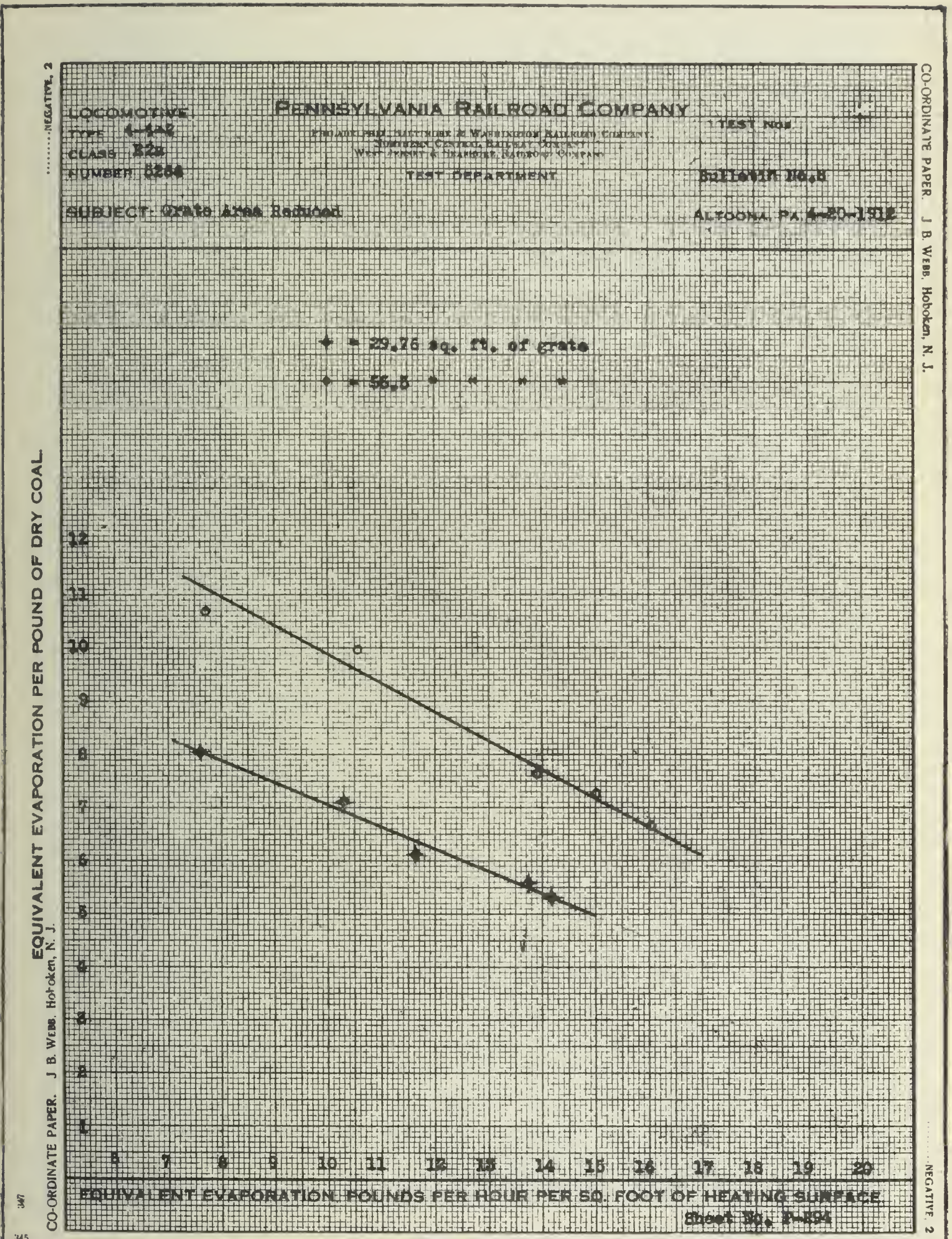
ALTOONA, PA., 8-10-07

TEST NUMBER	RUNNING CONDITIONS: TEST DESIGNATION	Duration of Test, Hours	Miles per Hour	Throttle Opening, Full or Partial	Actual Cut-off Per Cent., H. P. Cylinders	Coal	BOILER PERFORMANCE: Pressure in Boiler, Lbs. per Sq. Inch	Draft in Smoke Box, Inches of Water	Draft in Ash Pan, Inches of Water	Calorific Value of Dry Fuel, B. T. U. per Lb.	Cinders Collected in Smoke Box, Pounds per Hour
	R. P. M. Cut-off Throttle	196	199	203	268 to 271		217	222	225	248	238
946	80-30-F	3.00	19.10	6 1-2 notches	27.5	Penn	195.1	1.5	.0	14713	30
948	120-20-F	3.00	28.65	Full	18.4	Gas	202.1	3.5	.2	14713	42
945	160-25-F	2.50	38.20	"	23.8	"	200.4	5.5	.2	14713	93
947	160-32-F	2.00	38.20	"	32.9	"	182.6	7.2	.2	14713	128
940	80-15-F	3.00	19.10	"	14.5	Scalp	199.1	2.3	.1	15077	104
941	120-20-F	3.00	28.65	"	18.2	Level	196.9	3.5	.1	15077	324
943	80-30-F	2.50	19.10	"	29.9	"	202.7	3.9	.1	15077	327
942	160-25-F	1.33	38.20	"	24.3	"	195.1	5.7	.2	15077	388
944	160-25-F	1.67	38.20	"	24.0	"	187.8	6.1	.1	15077	775

TEST NUMBER	BOILER PERFORMANCE: Dry Fuel Fired per Hour, Pounds	Dry Fuel per Hour, Pounds per Sq. Ft. of Grate	Water Delivered to Boiler, Pounds per Hour	EQUIVALENT EVAPORATION FROM AND AT 212° F., POUNDS: Per Hour	Per Hour per Sq. Ft. of Fire Heating Sur.	Per Pound of Dry Fuel	Boiler Horse Power (34½ U. of E.)	Efficiency of Boiler, Based on Fuel	Draft in Fire-box.	ENGINE PERFORMANCE: Pressure in Branch Pipe, Pounds per Sq. In.	Superheat in Branch Pipe Degrees F.
	338	339	340	344	345	347	349	350		220	230
946	1246	41.87	11677	14178	6.11	11.38	411.0	74.70	0.6	96.3	
948	2345	78.80	20289	24812	10.70	10.58	719.2	69.45	1.3	199.3	
945	3772	126.75	26483	32820	14.15	8.70	951.3	57.11	2.7	195.8	
947	5014	168.48	33087	40426	17.43	8.06	1171.7	52.91	3.0	179.5	
940	2195	73.76	14527	17652	7.61	8.04	511.7	51.50	0.9	196.2	
941	3366	113.10	19613	23936	10.32	7.11	693.7	45.54	1.3	193.8	
943	4406	148.05	22050	26932	11.61	6.11	780.6	39.14	1.4	199.0	
942	6177	207.56	26917	32846	14.16	5.32	952.1	34.08	1.8	191.8	
944	5753	193.31	26080	31858	13.74	5.54	923.4	35.49	1.9	184.9	

TEST NUMBER	ENGINE PERFORMANCE: Dry Steam to Engines, Pounds per Hour	Indicated Horse Power	Dry Fuel per Indicated Horse Power Hour, Pounds	Dry Steam per Indicated Horse Power Hour, Pounds	C O Smoke-box gases.	LOCOMOTIVE PERFORMANCE: Drawbar Pull, Pounds	Dynamometer or Drawbar Horse Power	Dry Fuel per Dynamom. Horse Power Hour, Pounds	Dry Steam per Dynamom. Horse Power Hour, Pounds	Machine Efficiency of Locomotive, Per Cent.	Thermal Efficiency of Locomotive, per Cent., (Based on Fuel)	Smoke in Percent
	214	379	380	381		285	383	384	385	398	399	
946	11234	307.3	4.05	36.57	0	5084	259.0	4.81	43.39	84.28	3.60	2
948	19684	796.4	3.32	27.87	0	7336	560.5	4.18	35.13	79.35	4.14	22
945	26388	1031.8	3.66	25.58	0.3	8360	851.6	4.43	30.99	82.54	3.90	No record
947	32408	1232.4	4.07	26.30	0.7	9831	1001.5	5.10	32.97	81.26	3.39	38
940	13818	417.6	5.26	33.10	0	6712	341.9	6.42	40.43	81.87	2.63	No Record
941	18996	685.9	4.91	27.99	0	7092	541.9	6.21	35.42	79.01	2.72	
943	20889	720.0	6.12	29.30	0.47	12321	627.6	7.02	33.61	87.17	2.40	
942	26259	1019.3	6.06	25.95	0.60	8227	838.1	7.37	31.56	82.23	2.29	
944	25453	974.6	5.90	26.31	1.40	7795	794.1	7.24	32.29	81.48	2.33	

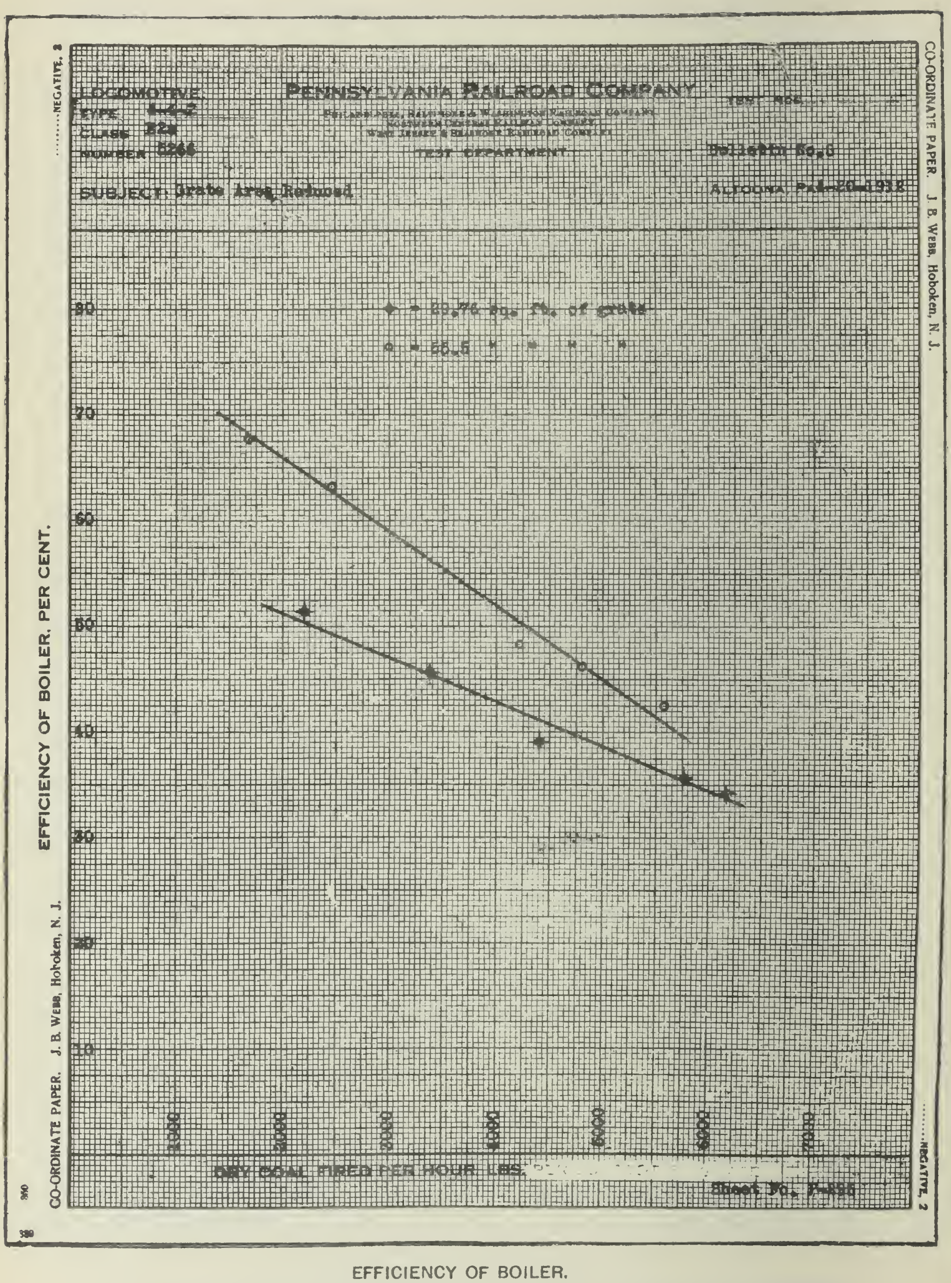
TESTS WITH THE GRATE REDUCED
as in Fig 3, and using both a high and low volatile coal.
Table 6.



EVAPORATION PER POUND OF COAL.

The upper line is for the full grate and the lower line, showing much less water per pound of coal, is for the grate blocked off to the smallest area. The coal used was Scalp Level, a low volatile light friable coal.

Fig. 4.



EFFICIENCY OF BOILER.

The large grate as shown by the upper line gives the best results. The coal has been plotted in total pounds per hour instead of per square foot of grate, because there were two sizes of grate. The coal used was Scalp Level.

Fig. 5.

tests was run on three sizes of grates to show the effect of changes in the grate area when using Penn Gas coal, which is

Table 1.

Test No.	Calorific Value, B. t. u. Per Pound			Kind of Coal	Grate Area Sq. Ft.
	Of Dry Coal	Cinders	Sparks		
901	15264	11713	10868	Scalp Level	55.5
908	15167	10606	8484	"	"
916	15264	9287	9042	"	"
917	15167	9701	11617	"	"
918	15167	11497	10899	"	"
950	14713	10808	19028	Penn Gas	55.5
951	14864	10659	9540	"	"
952	14864	11430	11017	"	"
953	14864	11312	10370	"	"
905	14411	11109	11109	Penn Gas	39.5
925	14411	9008	9298	"	"
926	14411	10691	10572	"	"
928	14411	9971	10452	"	"
940	15077	10227	10227	Scalp Level	29.76
941	15077	10868	11997	"	"
943	15077	11291	12216	"	"
942	15077	11351	11977	"	"
944	15077	10660	11677	"	"
946	14713	8623	10300	Penn Gas	29.76
948	14713	10061	11672	"	"
945	14713	11198	11618	"	"
947	14713	10898	11018	"	"

high in volatile combustible and is representative of the kind of coal used on passenger locomotives. The grate areas chosen were those referred to in the first portion of this report, namely: full, 39.5 and 29.76 square feet. With this coal, the results obtained are very different from those with the low volatile coal. Figs. 7,

8 and 9 and Tables 4, 5 and 6 show the results with the high volatile coal. Unless the boiler is forced to high rates of evaporation, the evaporation per pound of coal and the efficiency of the boiler are not much influenced by the reduction in the grate.

25. It is noticeable, however, that the full size grate gives an equivalent evaporation of 18.56 pound per square foot of heating surface, as a maximum, while with each reduction in grate the evaporation is decreased. It is 18.02 with the medium grate and 17.43 with the small grate. The full grate is none too large for high volatile coal, and a reduction in it limits the output of the boiler.

Cinders:

26. In Fig. 9 the cinders caught in the smokebox are shown with the dry coal fired per hour. At all rates of firing the cinders are increased with the blocking off of the grate, showing again that the full size grate is none too large.

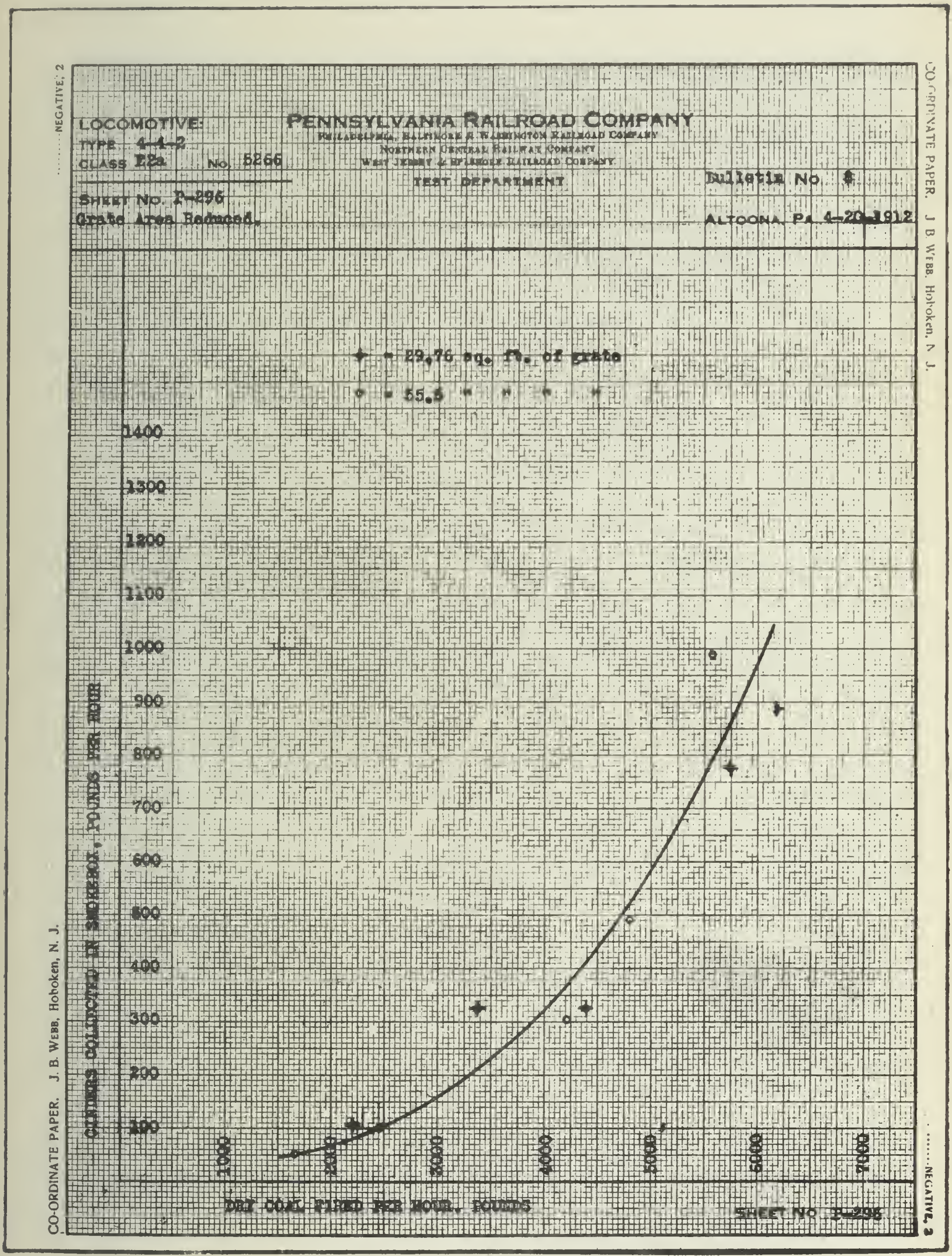
Smoke:

27. The smoke was observed during the trial with the high volatile coal with the results shown in Table 2.

TABLE 2.

Average Smoke (Ringelmann Scale) Penn Gas Coal.

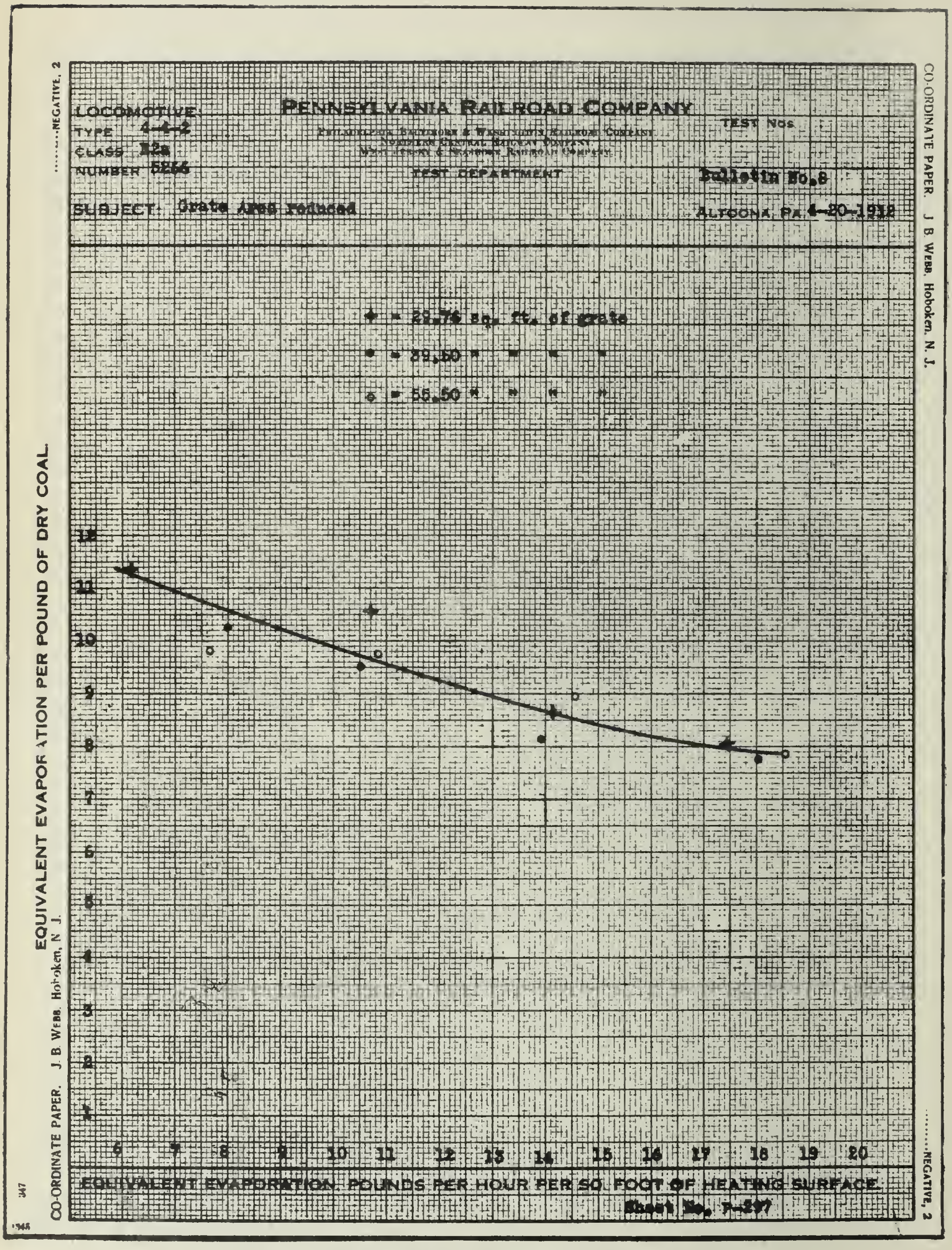
Test No.	Miles per Hour	Cut-Off	Throttle	Average Smoke in Per Cent	Analysis of Smoke-box Gases			Size of Grate
					Oxygen	C O	CO2	
950	19	15	Full	12	9.60	0	9.30	55.5sq.ft.
905	19	15	"	18	9.9	0	8.9	39.5 "
951	28	20	"	38	7.73	0	10.33	55.5 "
925	28	20	"	24	7.9	.07	10.3	39.5 "
948	28	20	"	22	7.33	0	11.0	29.76 "
952	38	25	"	46	7.07	.27	10.80	55.5 "
926	38	25	"	36	6.4	0	10.7	39.5 "
953	38	32	"	52	5.73	.67	11.13	55.5 "
928	38	32	"	52	4.4	.4	11.18	39.5 "
947	38	32	"	38	4.9	.70	11.9	29.76 "



CINDERS COLLECTED IN SMOKEBOX.

With this coal, Scalp Level, there is little difference between the two sizes of grate, in the quantity of cinders collected.

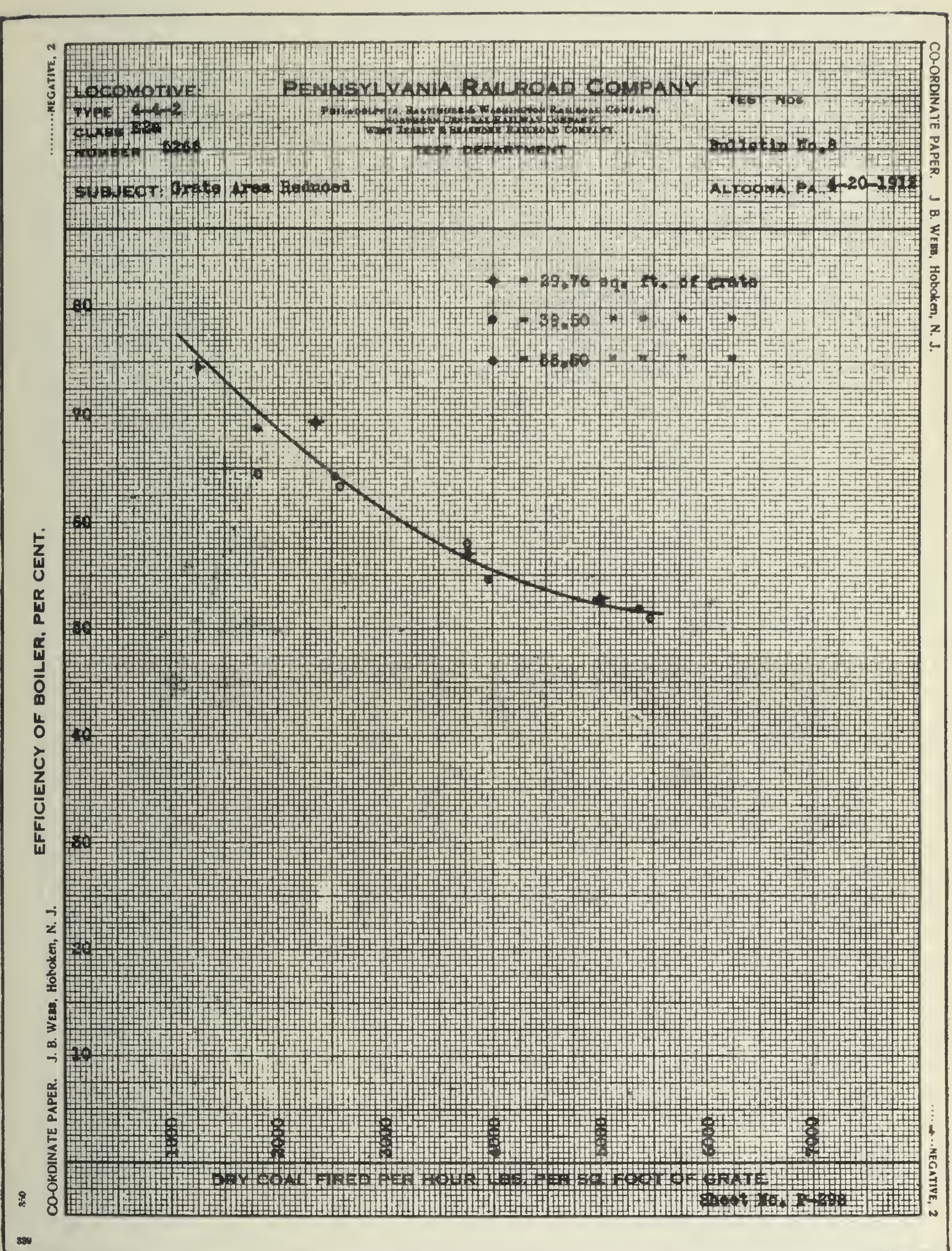
Fig. 6.



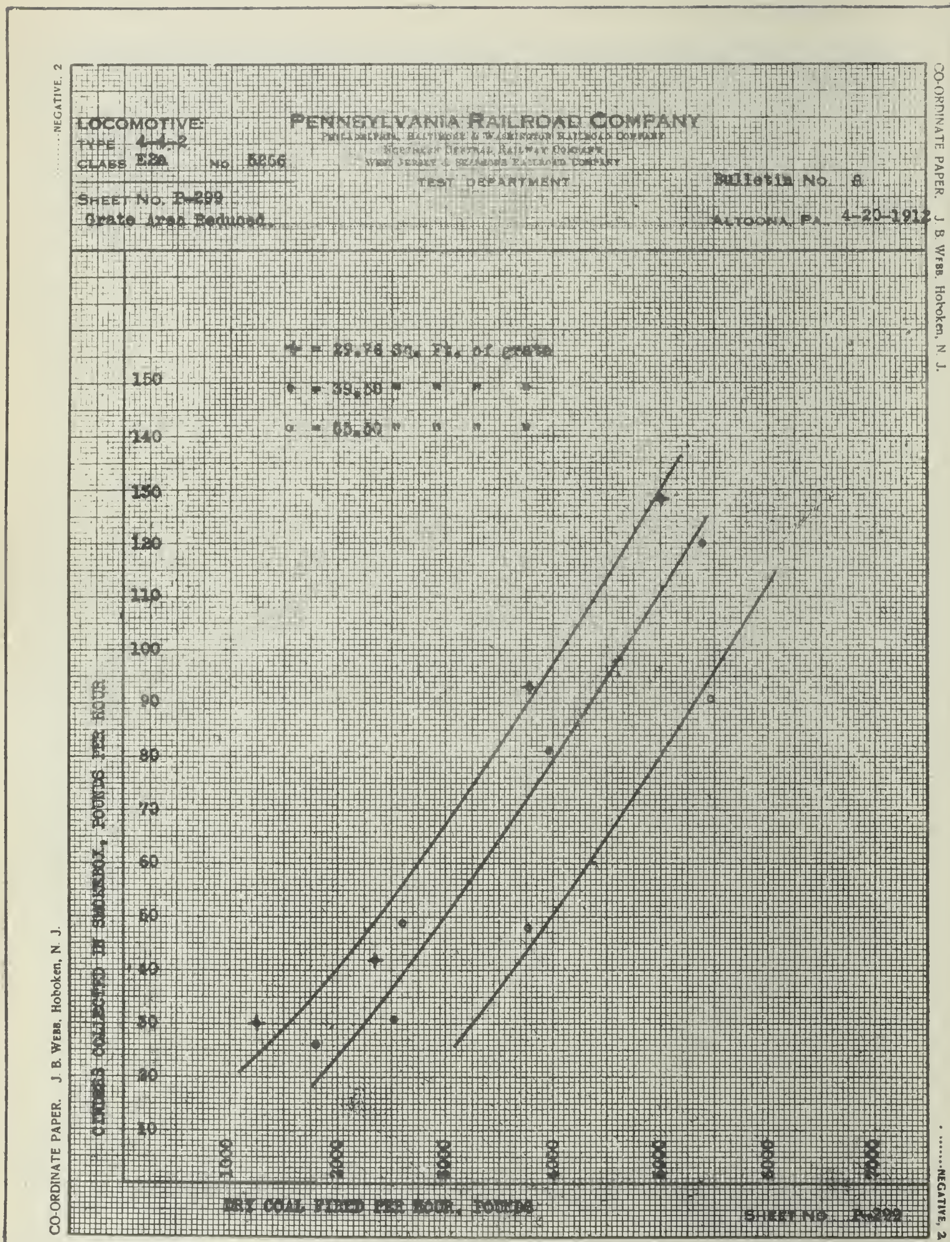
EVAPORATION PER POUND OF COAL, PENN GAS COAL.

With this coal the effect of the difference between the grates does not appear, except that the maximum evaporation is reduced with each reduction in grate area.

Fig. 7.



EFFICIENCY OF BOILER, PENN GAS COAL.
Three areas of grate.
Fig. 8.



CINDERS COLLECTED IN SMOKEBOX, PENN GAS COAL.

The effect of a reduction in grate surface is very clear on this diagram, and the large amount of cinders with the smaller grate indicates where the losses occur that limit the boiler capacity with the small grate.

Fig. 9.

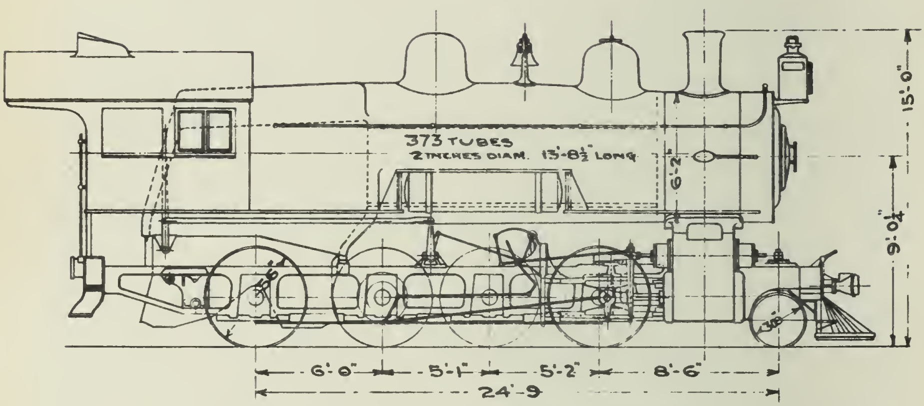
28. In general with this high volatile coal the smoke shown is less with the smaller grate than with the whole grate in use. The decrease in smoke is considerable with the smallest grate. There is a decrease of 27% in one case and 42% in the other.

29. The combustion on the small grate would appear from this to be better than the relatively slower combustion on the large grate, and this may be due to the combustion chamber that is formed at the front end of the grate over the blocked off portion.

30. The figures from the analysis of smokebox gases are too inconsistent to be used as the basis for any deductions in regard to combustion on the different grates.

31. After the tests on the E2a locomotive with the front end of the grate blocked off, a series of tests was made with a locomotive of the H6b class having the grate made solid around the edges.

32. As these tests are similar to the foregoing, in that part of the grate surface was blanked or blocked off, they will be described in what follows:



GENERAL ARRANGEMENT OF H6b CLASS LOCOMOTIVE.
Used in Solid End Grate tests.
Fig. 10.

GRATE WITH SOLID ENDS.

The second form of grate modification and results from its use.

INTRODUCTION.

33. For a long time past the Pennsylvania Railroad Company's locomotives have had grates with side bearing bars that fit close to the firebox sheets so that no air can enter the firebox between these bearers and the sheets. The sheets are thus protected, for a space of about 2 inches, from direct contact with cold air entering the furnace.

34. It has been proposed, in endeavoring to prevent smoke, that this protecting strip be widened and the air entering through the grate be compelled to come up at a greater distance from the firebox sheets, and tests of such an arrangement have been made. It was expected that this blocking of the grate would result in better combustion and evaporation and a reduction in the amount of smoke on account of the higher furnace temperature that would be possible. The results were not as anticipated, and no advantage was found in the use of the solid end grates. There was an increase in the smoke and no saving in coal from their use.

Description of Grate.

35. In order to test the effect of such a modification of the grate, a set of grates as shown in Figs. 11 and 12 were prepared for the H6b class locomotive. The photograph shows one section each of the front drop grate, half grate, filling piece and one section of the rocking or finger grate bar. The pieces shown, make up the forward end of the grate on one side of the firebox.

36. On the outside end, or the end of each grate bar nearest to the sheets, the openings through the grate have been closed up or the ends made solid. This solid part is about 6 inches wide, making a section of solid grate about 9 inches wide, if we include

the grate bearing bar, all the way around the firebox. The firebox sheets were thus protected more perfectly than is usual, and better combustion and less smoke was expected from this arrangement.

37. The total grate area, measured up to the firebox sheets is 48.66 square feet and the air openings through the grate with solid ends are a total of 15.41 square feet or 31.7 per cent of the grate area. The grate without the solid ends, or the standard grate for this locomotive, has air openings of 17.6 square feet or 36.4 per cent of the total grate surface.

The Tests.

38. Five tests of this grate were made and they were chosen so that they cover a wide range in evaporation. All of the tests were made with an H6b class locomotive, see Fig. 10. There were two speeds and cut-offs. For comparison with them, five other tests with this locomotive at similar speeds and cut-offs with the usual or standard grate have been selected.

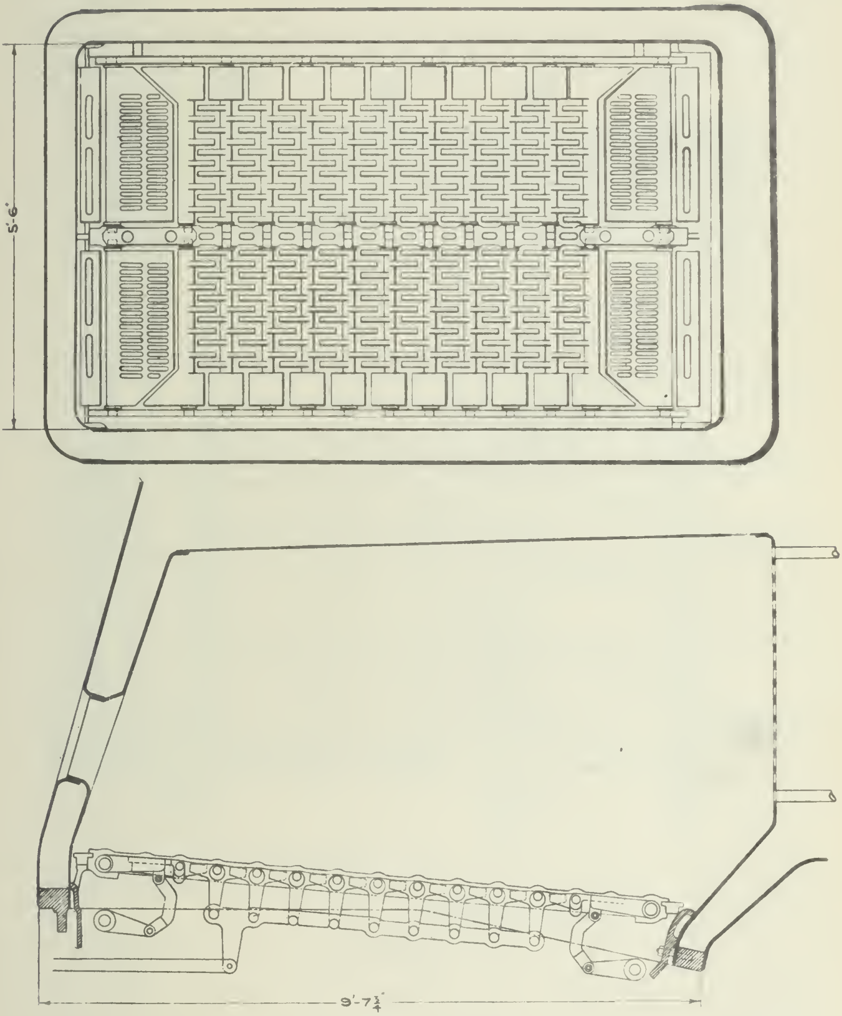
39. In all of the tests Jamison run-of-mine coal was used. The analysis of this coal is as follows:

Fixed Carbon	55.57
Volatile Combustible	31.59
Ash	11.95
Moisture	0.89
	100.00
Sulphur	2.21
B. t. u. per pound of dry coal	13540

The firing and handling of the locomotive were the same in all of the tests.

40. The results of the tests are shown on Table 9 and diagrams Figs. 13 to 16.

41. Table 7 showing observations of the smoke, would indicate that there is a trifle more smoke with the solid end grate than with the standard grate.



GRATE WITH SOLID ENDS.
As applied to H6b Class Locomotive.
Fig. 11.

TABLE 7.

Test Number		Test Designation			Average Smoke Number	
Standard Grate	Solid End Grate	M. P. H.	Cut-Off	Throttle	Standard Grate	Solid End Grate
1200.400	1200.405	12.86	20%	Full	12	14
1200.399	1200.406	12.86	30%	"	12	14
1200.401	1200.407	12.86	40%	"	12	16
1200 404	1200.408	19.3	40%	"	22	26
1200.410	1200.409	19.3	45%	"	32	30

This is further illustrated on the diagrams Figs. 13 and 14 which show the average smoke with coal fired and the average smoke with water evaporated.

42. On the diagram of evaporation per pound of coal and evaporation per square foot of heating surface (Fig. 15), no difference can be found between the two grates. The boiler capacity is apparently not limited to any great extent, by the use of this solid end grate.

CONCLUSIONS (GRATE AREA REDUCED).

43. It has been demonstrated that with a light friable coal which easily forms cinders and sparks in large quantities, the blocking off of the grate has a very bad effect and there can be no justification for making the large grate smaller. If the low volatile coal is to be used in locomotives which are operated at rates close to their capacity, there should be provided a larger grate area than is now customary.

44. With the gas coal the conclusions are not so decidedly in favor of the full grate, for with this coal there is a little less smoke with the smaller grates, but at the same time there is a reduction in the capacity of the boiler to generate steam which is a much more serious limitation to the usefulness of the locomotive than is compensated for by the slight reduction in smoke. We must conclude, therefore, that the methods of blocking off the

GRATE BARS WITH SOLID ENDS.
Each of the different shapes, which make up the whole grate, are shown. There are four of the drop grate sections and 18 of the finger grates.
Fig 12.

grate, that were investigated, result in limiting the power of the locomotive, and the slight advantages shown in ease of firing and reduction of smoke would better be secured in some other manner by which the locomotive's power would be increased, rather than diminished.

Recommendations (Grate Area Reduced).

45. These tests disclose the fact that any limitation of the active portion of the grate reduces the maximum capacity of the locomotive and the practice of reducing the grate should not be permitted with either high or low volatile coal.

Conclusions (Grates With Solid Ends).

46. From these tests it appears that there is no advantage shown by the solid grate. The evaporation per pound of coal is not improved, and there is more smoke than with the standard grate. (Paragraphs 41 and 42.)

Recommendations (Grates With Solid Ends).

47. There is little promise of important developments in smoke prevention from such devices as this solid end grate, and our recommendations are, that further efforts in the improvement of combustion be directed along other lines.

C. D. YOUNG,
Engineer of Tests.

Approved:

J. T. WALLIS,
General Supt. Motive Power.

Test Department.
Altoona, Penna.,
August 31, 1912.

M. P. 894A
N - 10½

7 6 1907

PENNSYLVANIA RAILROAD COMPANY

Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company

TEST DEPARTMENT

AVERAGE RESULTS OF LOCOMOTIVE TESTS

LOCOMOTIVE:
TYPE 2-8-0
CLASS H6b
NUMBER 2860

Bulletin No. 8
TEST NOS., 1200.399 to 1200.410

SUBJECT: Standard and Solid End Grates

ALTOONA, PA., 4-20-1912

	DRIVING WHEELS	
1	Number of Pairs	4
2	Approx. Diameter, inches	56
	ENGINE TRUCK WHEELS	
14	Number	2
15	Diameter, inches	30
	TRAILING WHEELS	
16	Diameter, inches	-
	WHEEL BASE, FEET	
17	Driving Wheel Base	16.25
18	Total Wheel Base	24.84
19	Gage of Wheels	4.75
	WEIGHT OF ENGINE WITH WATER AT 2D. GAGE COCK AND NORMAL FIRE, POUNDS	
20	On Truck	21667
21	" 1st Drivers	45667
22	" 2d "	42583
23	" 3d "	47500
24	" 4th "	40850
25	" 5th "	—
26	" Trailers	—
27	Total	198267
28	" on Drivers	176600
	CYLINDERS	
	Diam. and Stroke, H P	22 x 28
	" " " L. P	-
	CLEARANCE IN PER CENT. OF PISTON DISPLACEMENT	
40	H. P. Right, Head End	12.5
41	" " Crank "	10.7
42	" Left, Head "	12.2
43	" " Crank "	10.8
44	L. P. Right, Head "	-
45	" " Crank "	-
46	" Left, Head "	-
47	" " Crank "	-
	RECEIVER, CUBIC FEET	
48	Volume Right Side	-
49	" Left "	-
	STEAM PORTS, INCHES	
50	H. P. Admission, Length	30
51	" " Width	2
58	L. P. " Length	-
59	" " Width	-
66	H. P. Exhaust, Length	No port
67	" " Width	-
70	L. P. " Length	-
71	" " Width	-

	PISTON RODS, DIAMETER INCHES	
74	High Pressure	4
76	Low "	-
	TAIL RODS, DIAMETER, INCHES	
78	High Pressure	
80	Low "	-
	VALVES	
82	Type	Piston
83	Design	Amr. Bal. Valve Co.
84	Per Cent. Balanced	100
85	Type of Valve Motion	Walschaerts
	GREATEST VALVE TRAVEL	
86	High Pressure, inches	6.25
88	Low " "	-
	Steam LAP OF VALVE	
90	High Pressure, inches	.91
94	Low " "	-
	Exhaust LAP OF VALVE	
98	High Pressure, inches	Neg. .06
102	Low " "	-
	BOILER	
113	Type	Belpaire, Wide Firebox
114	Outside Diam. 1st Ring	71.16
	TUBES	
115	Number	373
116	Outside Diam., inches	2
	Pitch "	2.6875
118	Length Between Tube Sheets, inches	164.28
119	Total Fire Area, sq. ft.	6.23
124	Boiler Pressure, pounds	205
	SUPERHEATER	
125	Number of Tubes	-
126	Outside Diam. " inches	-
128	Length of " "	-
	FIREBOX, INSIDE, INCHES	
132	Length	118.32
133	Width	65.04
137	Air Inlets to Ashpan, sq. ft.	7.56
	GRATES	
144	Type	Rocking finger
145	Grate Area, sq. ft.	48.66
146	Area of Dead Grates	0
	Air inlets through grates sq. ft.	15.41

	HEATING SURFACE, SQUARE FEET	
154	Of the Tubes, Water Side	2673.68
155	" " " Fire "	2339.23
156	" " Firebox, " "	166.06
157	" " Superh'r, " "	—
*158	Total, Based on " "	2505.29
159	" " " " " of Firebox and Water Side of Tubes	2839.74
	BOILER VOLUME WITH WATER SURFACE AT LEVEL OF 2D GAGE COCK	
160	Water Space, cu. ft.	349.7
161	Steam " " "	83.1
	EXHAUST NOZZLE	
162	Double or Single	Single
163	Size, inches	5.63
167	Area, sq. inches	24.89
	REVERSE LEVER	
168	H. P. Notches Forward of Center	22
169	L. P. Notches Forward of Center	—
	RATIOS	
171	Heating Surface (158) to Grate Area (145)	51.49
172	Fire Area Thru Tubes (119) to Grate Area (145)	.13
173	Firebox Heating Surface (156) to Grate Area (145)	3.41
174	Tube Heating Surface (155) to Fire Box Heating Surface (156)	14.09

*USED IN CALCULATIONS

DIMENSIONS OF THE H6b CLASS LOCOMOTIVE
on which the solid end grate tests were made.
Table 8.

M. P. 394 A—Sixth Sheet
8 x 10½

11-9-10

PENNSYLVANIA RAILROAD COMPANY

Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company

TEST DEPARTMENT

AVERAGE RESULTS OF LOCOMOTIVE TESTS

LOCOMOTIVE:
TYPE 2-8-0
CLASS H6b
NUMBER 2860

Bulletin No. 8
FUEL: Jamison Coal

SUBJECT: Standard and Solid End Grate

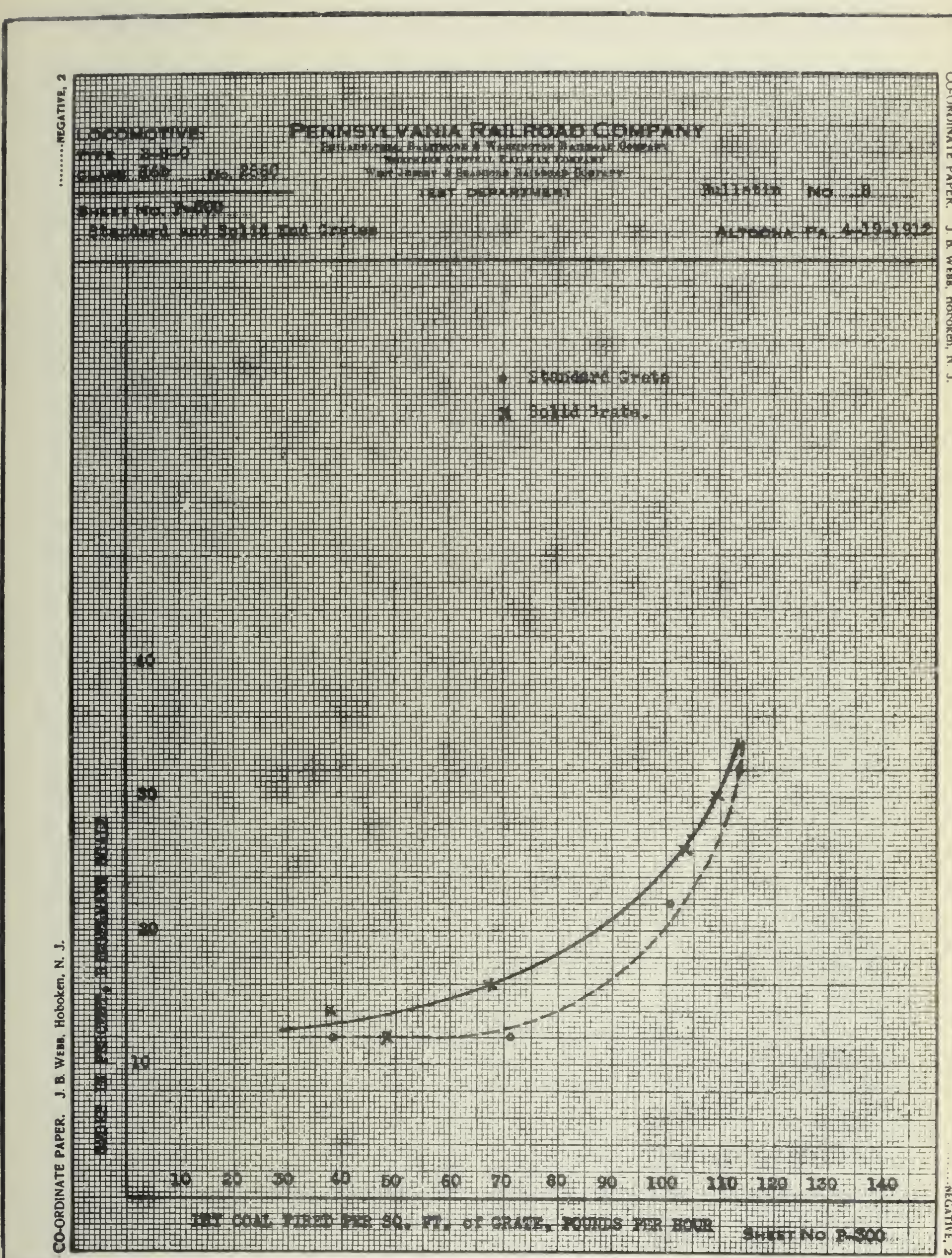
ALTOONA, PA., 4-20-1912

TEST NUMBER	RUNNING CONDITIONS: Test Designation	Duration of Test, Hours	Miles per Hour	Throttle Opening, Full or Partial	Actual Cut-off Per Cent., H. P. Cylinders	Kind of Grate	BOILER PERFORMANCE: Pressure in Boiler, Lbs. per Sq. Inch	Draft in Smoke Box, Inches of Water	Draft in Ash Pan, Inches of Water	Calorific Value of Dry Fuel, B. T. U. per Lb.	Cinders Collected in Smoke Box, Pounds per Hour
	R. P. M. Cut-off Throttle	196	199	203	268 to 271		217	222	225	248	238
1200.400	80-20-F	2	12.86	Full		Standard	202.4	1.5	0	13540	19
1200.399	80-30-F	2	12.86	"		"	204.8	2.1	0	13393	24
1200.401	80-40-F	2	12.86	"		"	203.8	3.6	0	13540	69
1200.404	120-40-F	2	19.30	"		"	198.3	5.3	0.1	"	94
1200.410	120-45-F	1	19.30	"		"	202.9	5.6	0.2	"	254
1200.405	80-20-F	2	12.86	"		Solid End	204.8	1.4	-	"	17
1200.406	80-30-F	2	12.86	"		"	203.0	2.1	0.1	"	27
1200.407	80-40-F	2	12.86	"		"	205.1	3.4	0.1	"	37
1200.408	120.40-F	2	19.30	"		"	187.8	5.0	0.1	"	94
1200.409	120-45-F	1	19.30	"		"	193.4	5.5	0.2	"	254

TEST NUMBER	BOILER PERFORMANCE: Dry Fuel Fired per Hour, Pounds	Dry Fuel per Hour, Pounds per Sq. Ft. of Grate	Water Delivered to Boiler, Pounds per Hour	Equivalent Evaporation from and at 212° F., Pounds: Per Hour	Per Hour per Sq. Ft. of Fire Heating Sur.	Per Pound of Dry Fuel	Boiler Horse Power (34½ U. of E.)	Efficiency of Boiler, Based on Fuel	Draft in Firebox	ENGINE PERFORMANCE: Pressure in Branch Pipe, Pounds per Sq. In.	Superheat in Branch Pipe Degrees F.
	338	339	340	344	345	347	349	350		220	230
1200.400	1857	38.16	14850	18237	7.28	9.82	528.6	70.05	0.7		
1200.399	2346	48.21	17678	21509	8.59	9.17	623.4	66.13	0.8		
1200.401	3469	71.29	23844	29046	11.59	8.37	841.9	59.70	1.3		
1200.404	4893	100.56	30625	37273	14.88	7.62	1080.4	54.35	2.0		
1200.410	5530	113.65	33058	40153	16.03	7.26	1163.9	51.79	2.0		
1200.405	1833	37.68	14435	17457	6.97	9.52	506.0	67.91	0.6		
1200.406	2340	48.09	17416	21186	8.46	9.05	614.1	64.55	0.8		
1200.407	3274	67.28	23467	28643	11.43	8.75	830.2	62.41	1.2		
1200.408	5042	103.62	31010	37785	15.08	7.49	1095.2	53.43	1.9		
1200.409	5318	109.29	32510	39584	15.80	7.44	1147.4	53.06	2.2		

TEST NUMBER	ENGINE PERFORMANCE: Dry Steam to Engines, Pounds per Hour	Indicated Horse Power	Dry Fuel per Indicated Horse Power Hour, Pounds	Dry Steam per Indicated Horse Power Hour, Pounds	C O in Gases	LOCOMOTIVE PERFORMANCE: Drawbar Pull, Pounds	Dynamometer or Drawbar Horse Power	Dry Fuel per Dynamom. Horse Power Hour, Pounds	Dry Steam per Dynamom. Horse Power Hour, Pounds	Machine Efficiency of Locomotive, Per Cent.	Thermal Efficiency of Locomotive, per Cent., (Based on Fuel)	Smoke in Per cent
	214	379	380	381		285	383	384	385	398	399	
1200.400	14308				0	14034	481.4	3.86	29.72		4.87	12
1200.399	17400				0	18827	645.8	3.63	26.94		5.23	12
1200.401	23466				0.2	24968	856.5	4.05	27.40		4.64	12
1200.404	30254				0	20301	1044.6	4.68	28.96		4.02	22
1200.410	32658				0.8	21743	1118.7	4.94	29.19		3.80	32
1200.405	14220				0	14176	486.3	3.77	29.24		4.99	14
1200.406	17205				0	18497	634.5	3.69	27.12		5.09	12
1200.407	23170				0.4	25051	859.3	3.81	26.96		4.93	16
1200.408	30635				0	21002	1080.7	4.67	28.35		4.02	26
1200.409	32102				0.8	20564	1058.1	5.03	30.34		3.74	30

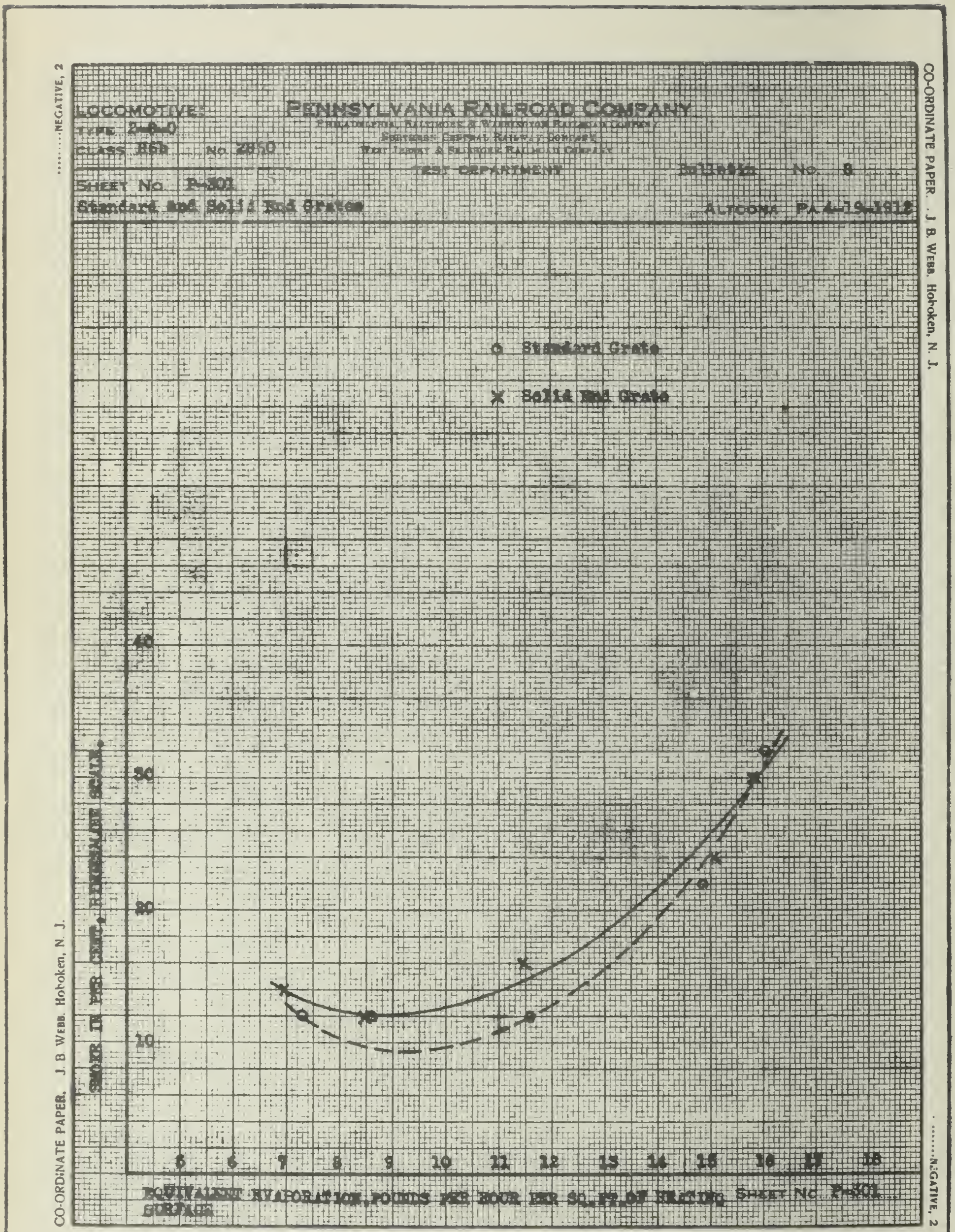
RESULTS OF TESTS OF SOLID END AND STANDARD GRATES.
Jamison Coal.
Table 9.



SMOKE, AND COAL FIRED.

The solid end grates make a little more smoke than the regular form of grate. Jamison Coal.

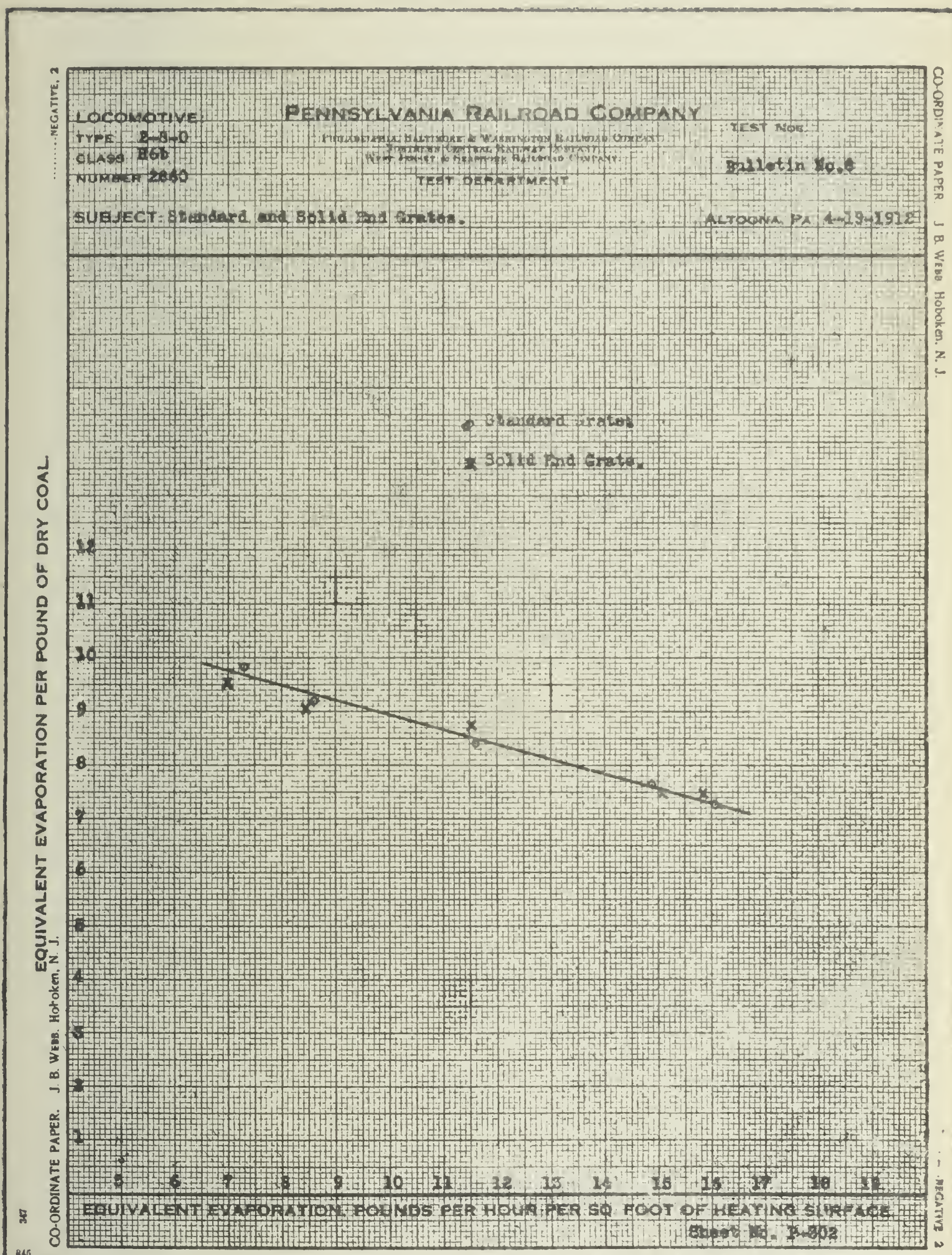
Fig. 13.



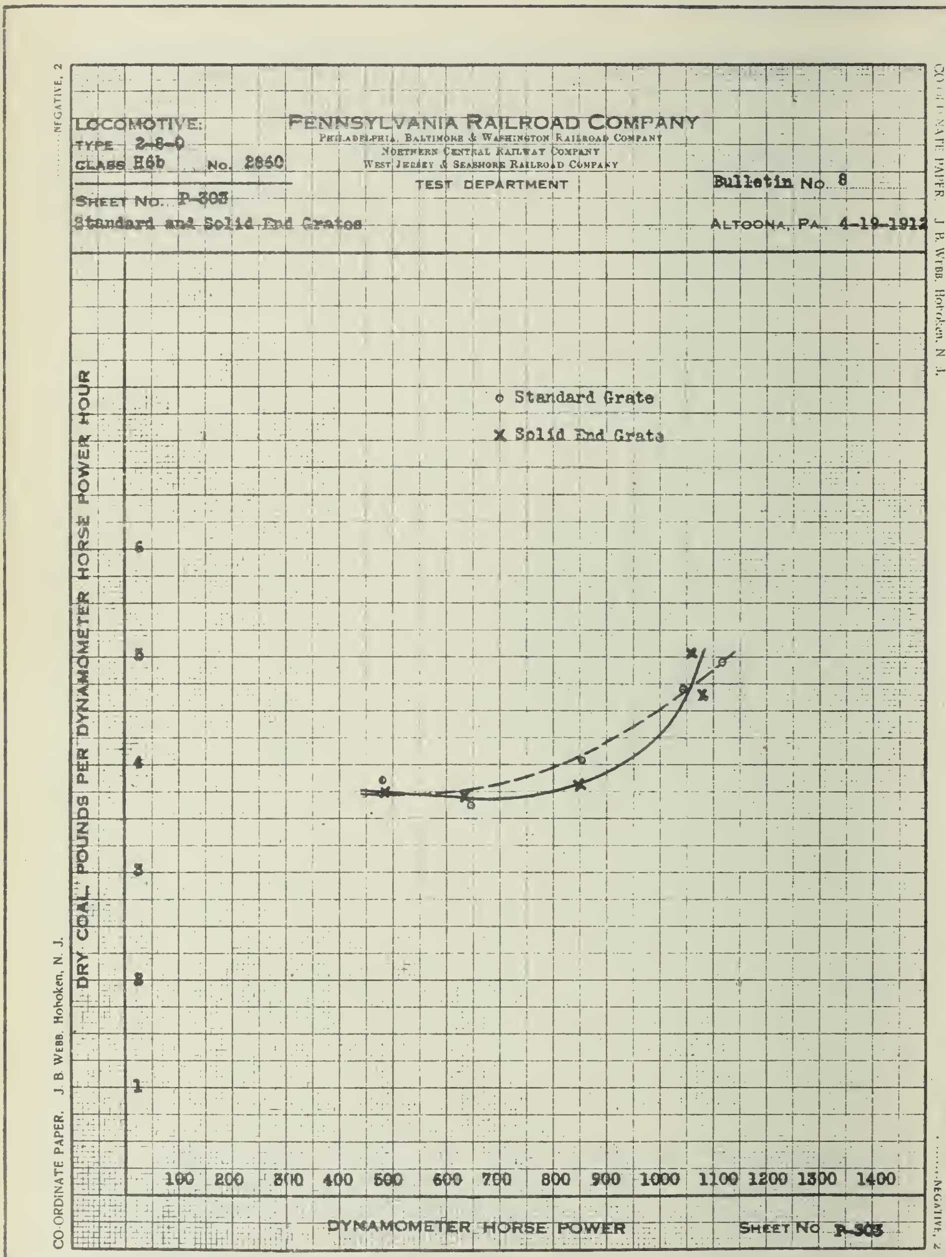
SMOKE AND EVAPORATION.

The solid end grate again shows more smoke than the standard grate. Jamison Coal.

Fig. 14.



EVAPORATION PER POUND OF COAL AND RATE OF EVAPORATION.
No difference can be found between the two grates. Jamison Coal.
Fig. 15.



COAL PER DYNAMOMETER OR DRAWBAR HORSEPOWER, AND DYNAMOMETER HORSEPOWER.

There is little or no difference between the two grates. Jamison Coal.

Fig. 16.

GRAPHICAL LOG OF TEST.

The following diagrams show the boiler pressure, speed, drawbar pull and weight of coal and water for each ten minute interval of the test. A diagram is drawn for each test and is on file with the Test Plant records. A few representative diagrams are shown here.

M. P. Experimental D-1

12 9 1911
6 x 10¾

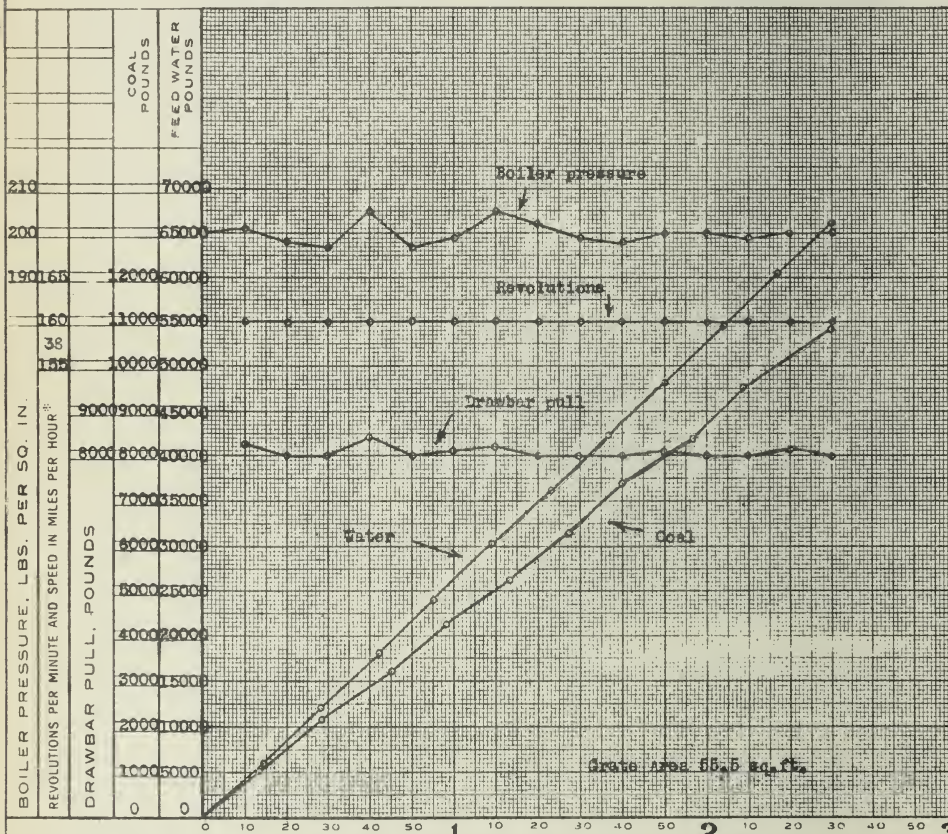
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-314 TEST DEPARTMENT Bulletin NO. 8

GRAPHICAL LOG OF LOCOMOTIVE TEST

Grate Area Reduced ALTOONA, PA., 12-19-06



*UPPER FIGURES R. P. M.
LOWER FIGURES APPROX. SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 4-4-2
CLASS E2a
NUMBER 5266

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
38.2	160	25	Full	6.11

TEST NO. 916

SHEET NO. P-314

M. P. Experimental D-1

12 9 1911
8 x 10½

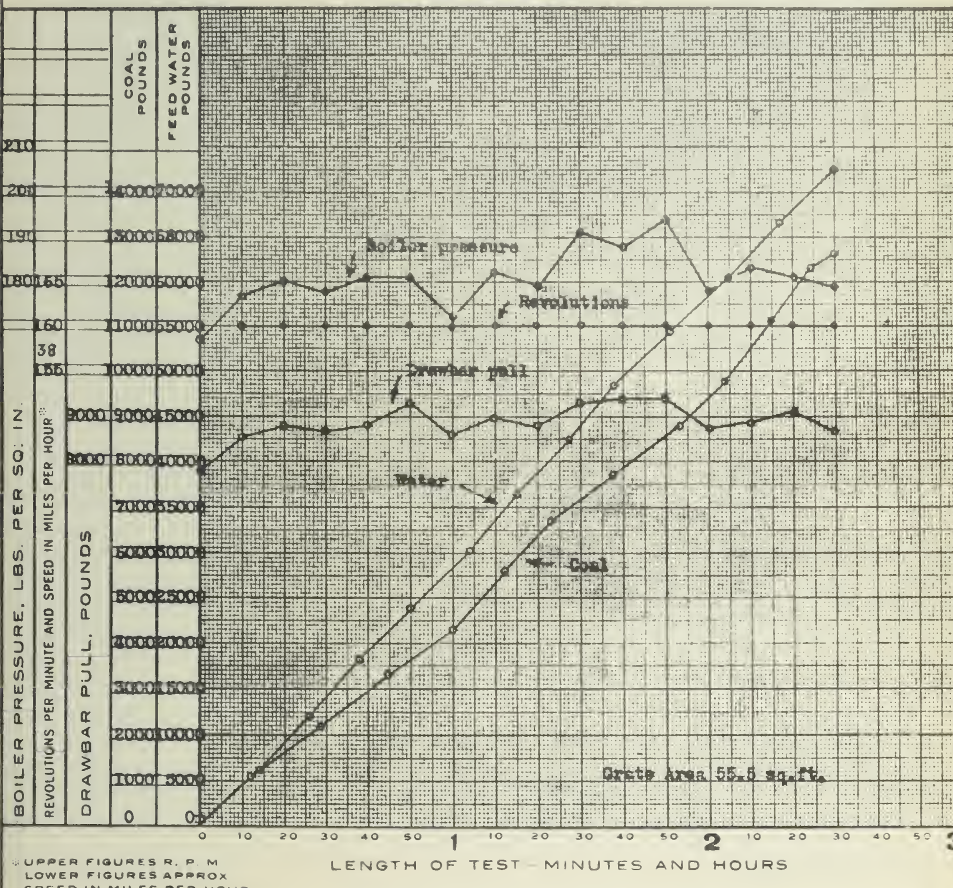
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-315 TEST DEPARTMENT Bulletin NO. 8

GRAPHICAL LOG OF LOCOMOTIVE TEST

Grate Area Reduced ALTOONA, PA. 11-28-06



*UPPER FIGURES R. P. M.
LOWER FIGURES APPROX
SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 4-4-2
CLASS E2a
NUMBER 5266

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
38.2	160	27	Full	5.73

TEST NO. 917

SHEET NO. P-315

M P. Experimental D-1

12 0 1911
8 x 1014

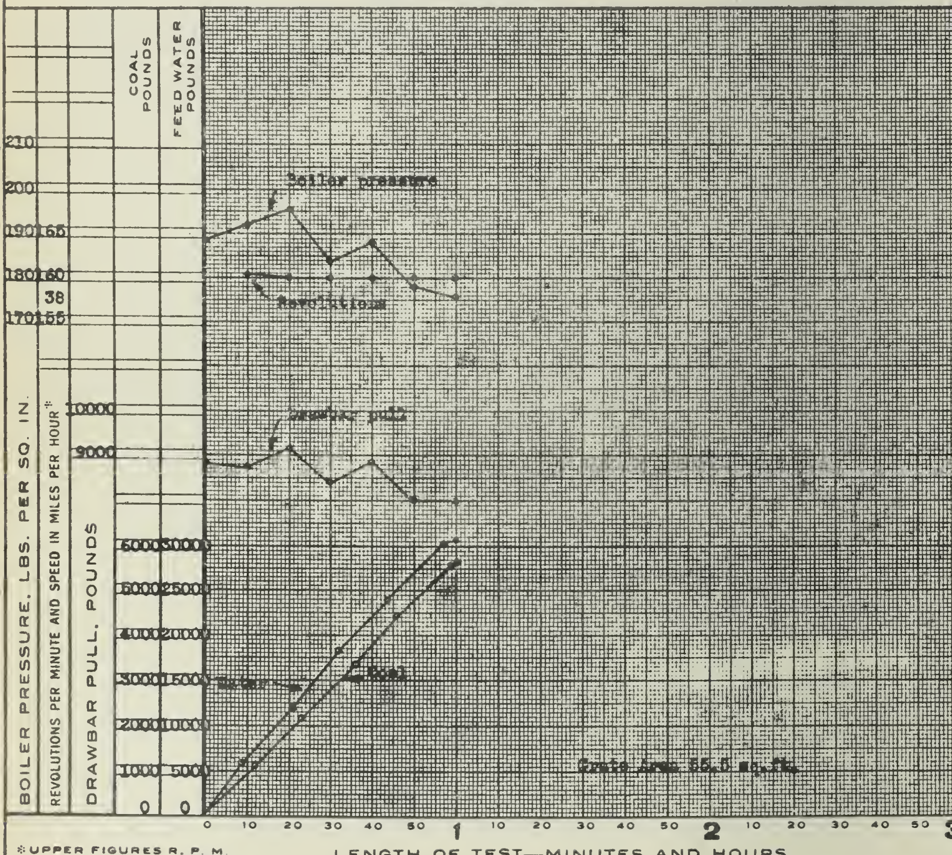
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-316 TEST DEPARTMENT Bulletin NO. 8

GRAPHICAL LOG OF LOCOMOTIVE TEST

Grate Area Reduced ALTOONA, PA., 11-26-06



*UPPER FIGURES R. P. M.
LOWER FIGURES APPROX.
SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 4-4-2
CLASS E2a
NUMBER 5266

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
38.2	160	30	Full	5.43

TEST NO. 918

SHEET NO. P-316

M. P. Experimental D-1

13-9-1911
8 x 10½

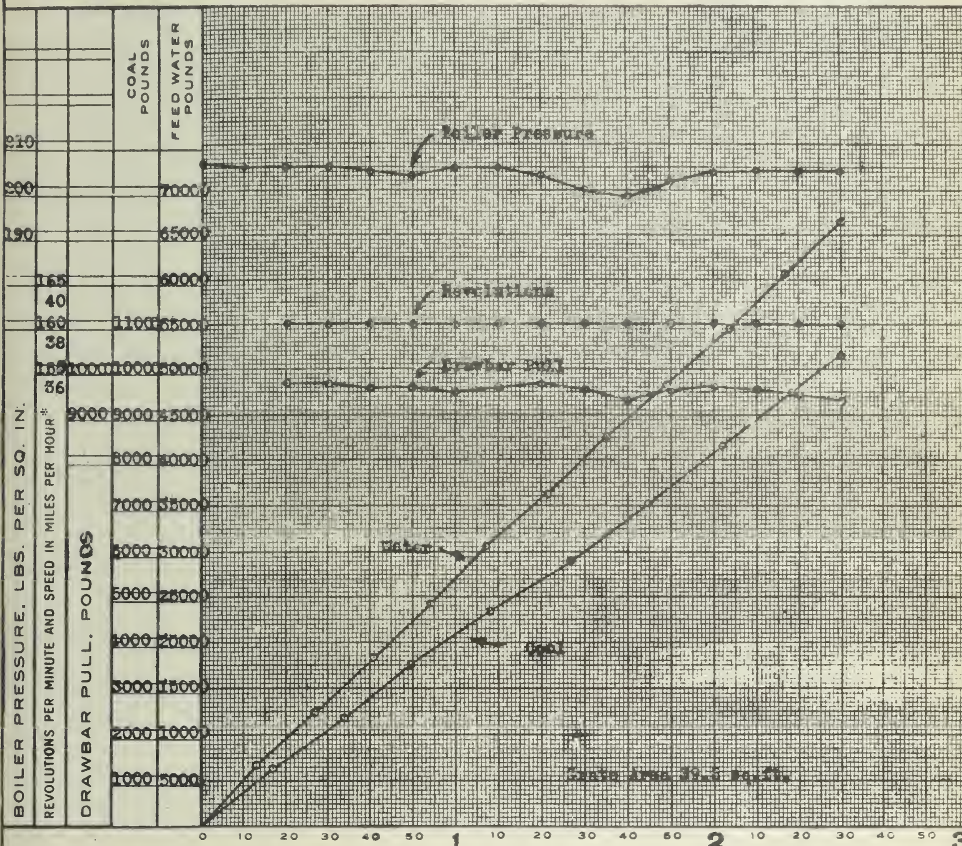
Pennsylvania Railroad Company

Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company

Sheet No. P-317 | Test Department | Bulletin No. 8

Graphical Log of Locomotive Test

Grate Area Reduced. | Altoona, Pa. 4-10-1907



*Upper figures R. P. M.
Lower figures approx. speed in miles per hour

Locomotive
Type 4-4-2
Class E2a
Number 5266

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
37.78	160	25	Full	6.62

Test No. 926

Sheet No. P-317

M. P. Experimental D-1

12 9 1911
8 x 10½

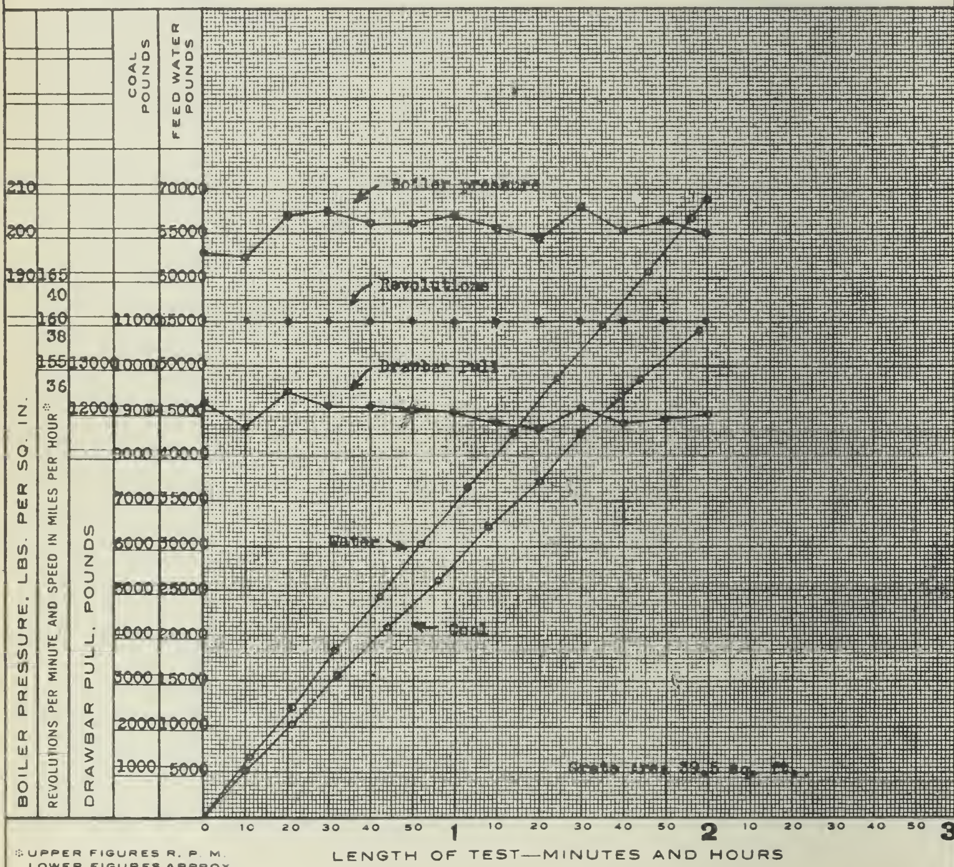
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-318 TEST DEPARTMENT Bulletin NO. 8

GRAPHICAL LOG OF LOCOMOTIVE TEST

Grate Area Reduced. ALTOONA, PA., 4-11-1907



* UPPER FIGURES R. P. M.
LOWER FIGURES APPROX.
SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 4-4-2
CLASS E2a
NUMBER 5266

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
37.78	160	32	Full	6.29

TEST NO. 928

SHEET NO. P-318

M. P. Experimental D-1

12 9 1911
8 x 10½

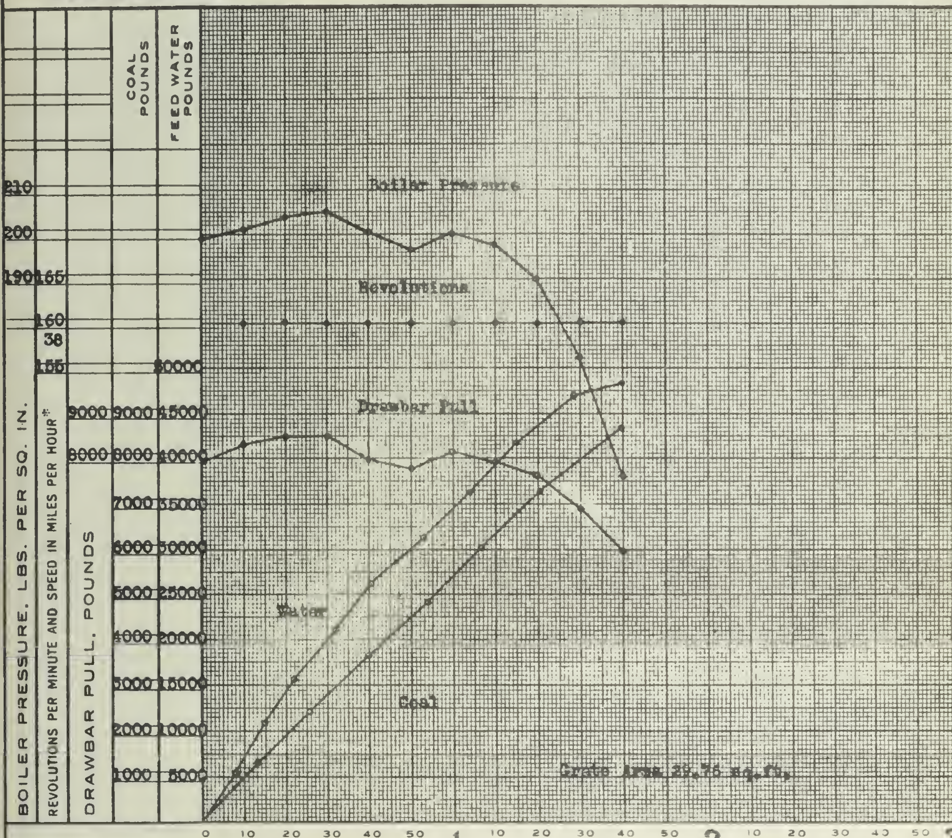
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-319 TEST DEPARTMENT Bulletin NO. 8

GRAPHICAL LOG OF LOCOMOTIVE TEST

Grate Area Reduced ALTOONA, PA., 1-29-1907



* UPPER FIGURES R. P. M.
LOWER FIGURES APPROX SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 4-4-2
CLASS E2a
NUMBER 5266

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
38.2	160	25	Full	5.57

TEST NO. 944

SHEET NO. P-319

M. P. Experimental D-1

12 9 1911
8 x 10½

PENNSYLVANIA RAILROAD COMPANY

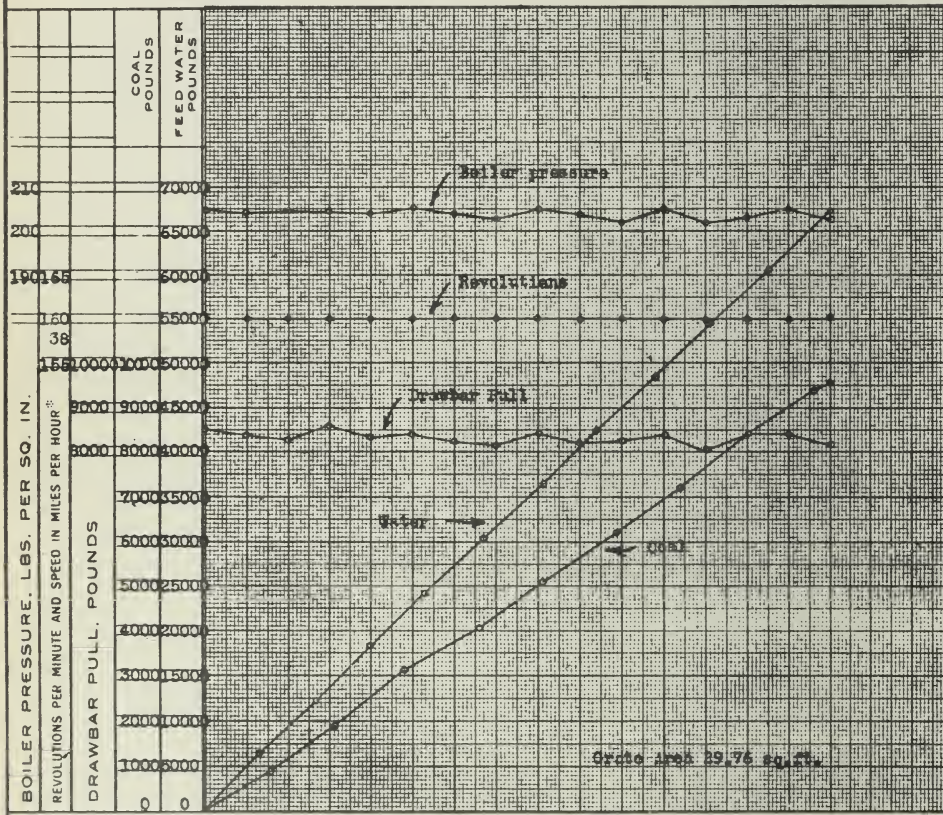
PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-320 | TEST DEPARTMENT | Bulletin | NO. 8

GRAPHICAL LOG OF LOCOMOTIVE TEST

Grate Area Reduced

ALTOONA, PA., 1-31-07



* UPPER FIGURES R. P. M.
LOWER FIGURES APPROX.
SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 4-4-2
CLASS E2a
NUMBER 5266

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
38.2	160	25	Full	7.04

TEST NO. 945

SHEET NO. P-320

M. P. Experimental D-1

12 x 1911
8 x 10½

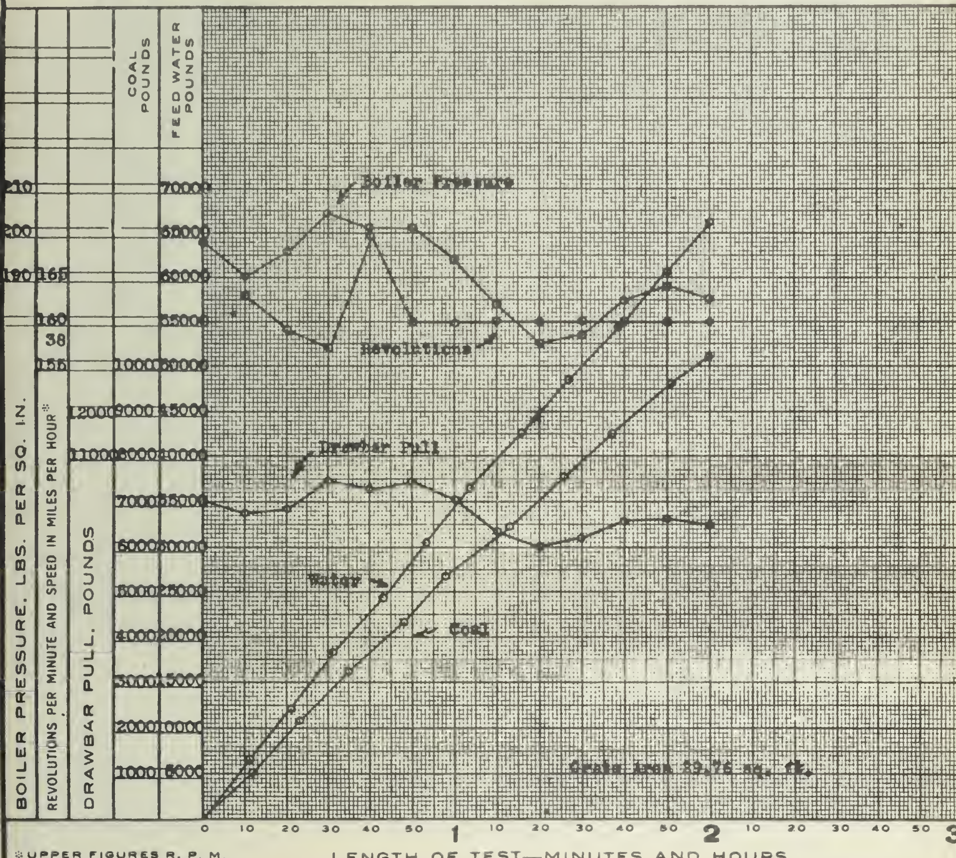
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO P-321 TEST DEPARTMENT Bulletin NO. 8

GRAPHICAL LOG OF LOCOMOTIVE TEST

Grate Area Reduced. ALTOONA, PA., 2-5-1907



*UPPER FIGURES R. P. M.
LOWER FIGURES APPROX. SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 4-4-2
CLASS E2a
NUMBER 5266

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
38.20	160	32	Full	6.62

TEST NO. 947

SHEET NO. P-321

M. P. Experimental D-1

12 9 1911
8 x 10½

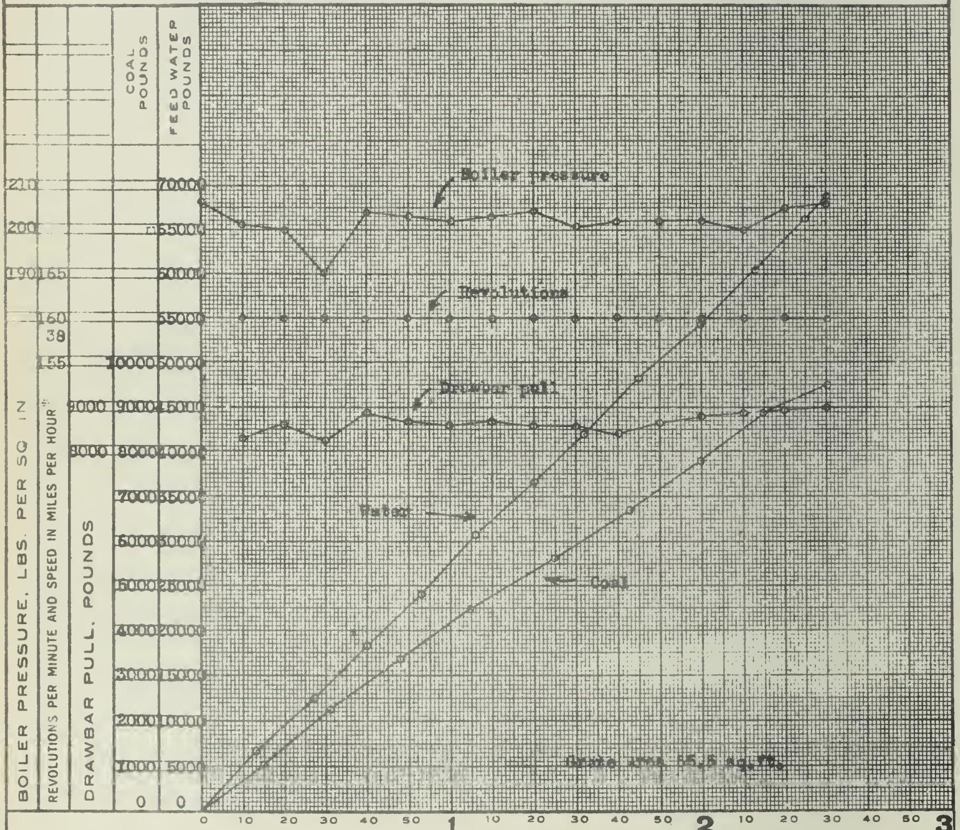
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-322 TEST DEPARTMENT Bulletin NO. 8

GRAPHICAL LOG OF LOCOMOTIVE TEST

Grate Area Reduced ALTOONA, PA., 3-8-07



*UPPER FIGURES R. P. M
LOWER FIGURES APPROX.
SPEED IN MILES PER HOUR

LENGTH OF TEST—MINUTES AND HOURS

LOCOMOTIVE
TYPE 4-4-2
CLASS E2a
NUMBER 5266

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
38.0	160	25	Full	7.23

TEST NO. 952

SHEET NO. P-322

M P Experimental D-1

12 9 1911
8 x 10½

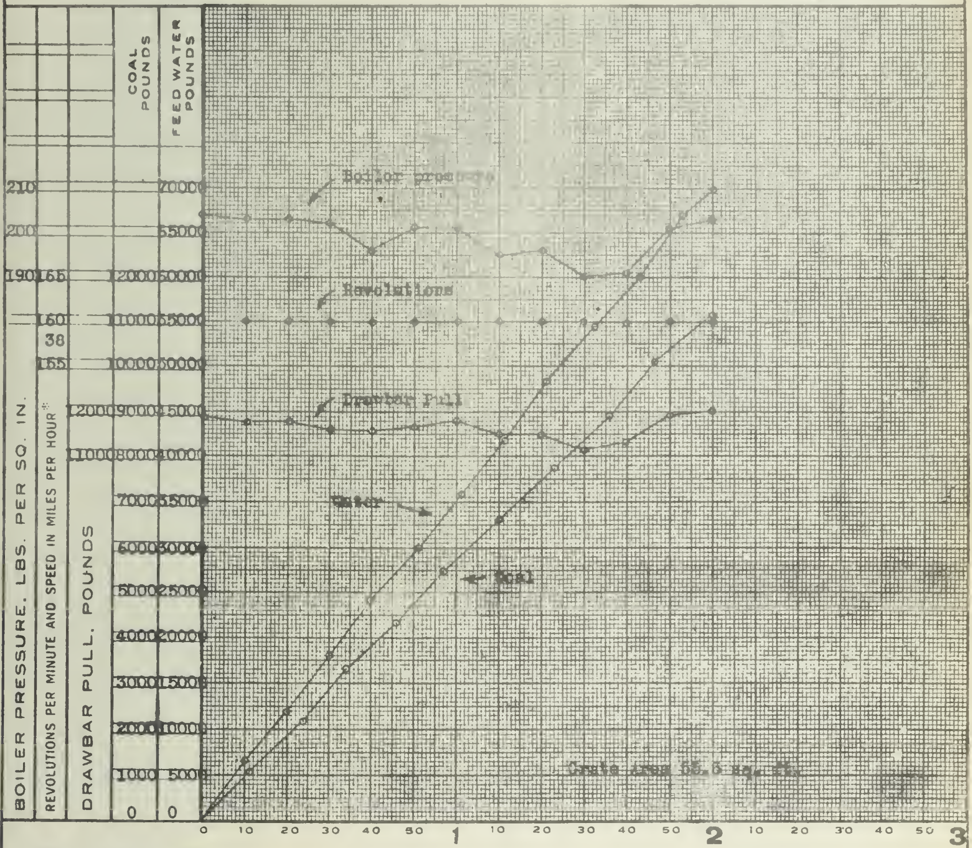
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-323 TEST DEPARTMENT Bulletin NO 8

GRAPHICAL LOG OF LOCOMOTIVE TEST

Grate Area Reduced ALTOONA, PA. 3-9-07



*UPPER FIGURES R. P. M
LOWER FIGURES APPROX. SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 4-4-2
CLASS E2a
NUMBER 5266

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
38.0	160	32	Full	6.33

TEST NO. 953

SHEET NO. P-323

M. P. Experimental D-1

12 9 1911
8 x 10½

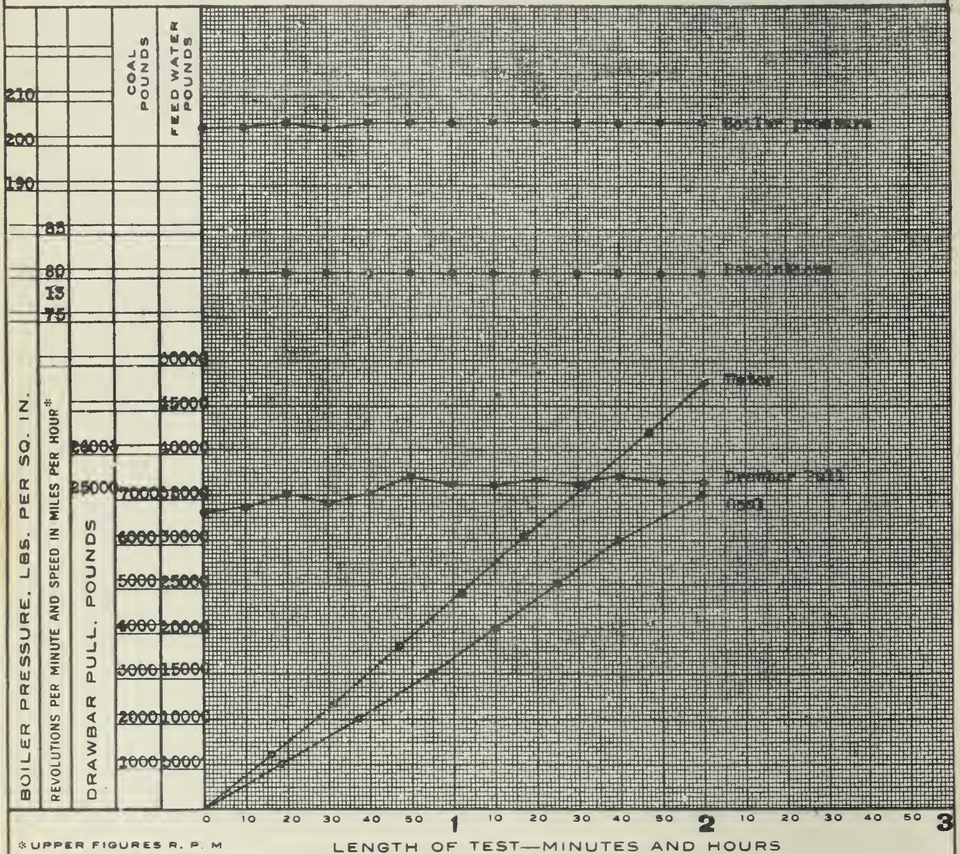
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-324 TEST DEPARTMENT Bulletin NO. 8

GRAPHICAL LOG OF LOCOMOTIVE TEST

Grates With Solid Ends ALTOONA, PA. 12-17-1909



* UPPER FIGURES R. P. M.
LOWER FIGURES APPROX.
SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 2-8-0
CLASS H6b
NUMBER 2860

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
12.86	80	40	Full	6.81

TEST NO. 1200.401

SHEET NO. P-324

M. P. Experimental D-1

13 9 1911
8 x 10½

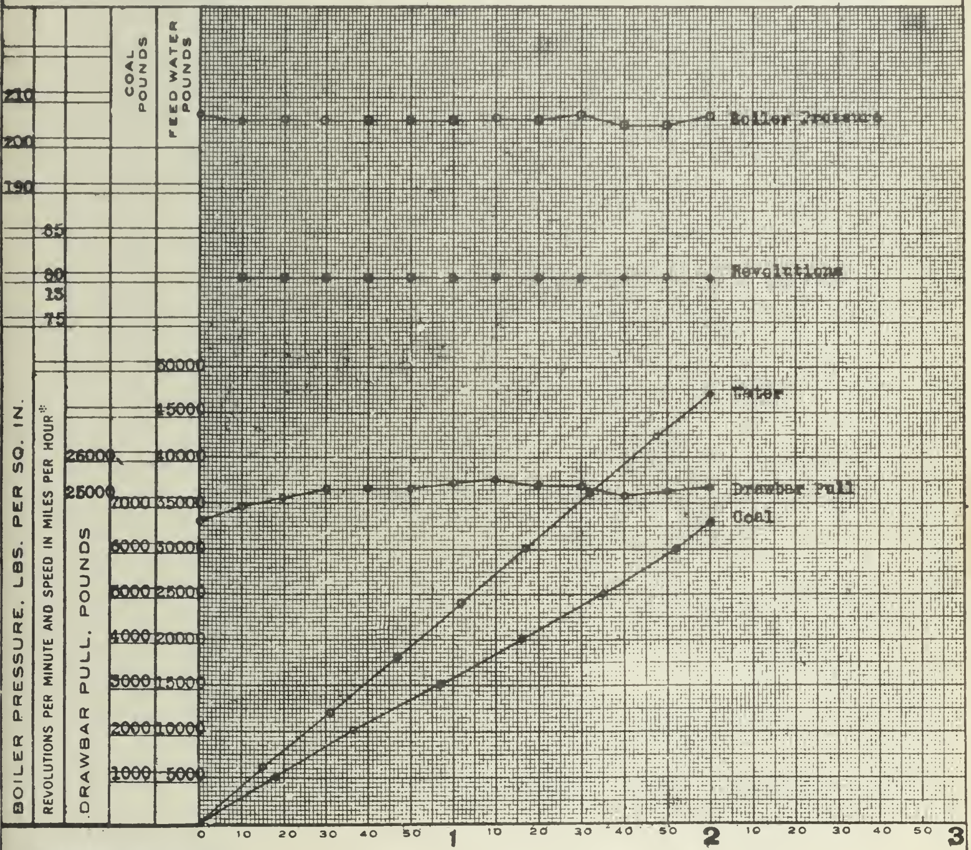
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-325 TEST DEPARTMENT Bulletin No. 8

GRAPHICAL LOG OF LOCOMOTIVE TEST

Grates with Solid Ends ALTOONA, PA., 12-22-1909



*UPPER FIGURES R. P. M
LOWER FIGURES APPROX.
SPEED IN MILES PER HOUR

LENGTH OF TEST—MINUTES AND HOURS

LOCOMOTIVE
TYPE 2-8-0
CLASS H6b
NUMBER 2860

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
12.86	80	40	Full	7.10

TEST No. 1200.407

SHEET No. P-325

PENNSYLVANIA RAILROAD COMPANY

Locomotive Testing Plant

AT

ALTOONA, PENNA.

BULLETIN No. 9 (REVISED)

Formerly Bulletins Nos. 11 and 28

SELF-CLEANING FRONT END

1912

THE E3a CLASS ATLANTIC TYPE LOCOMOTIVE.
The type of locomotive used in the Front End tests.

CONTENTS.

I. Self-Cleaning Front End for E Class Locomotive.

II. Self-Cleaning Front End with H6b Class Locomotive.

LOCOMOTIVE TESTING PLANT.

SELF-CLEANING FRONT END FOR E CLASS LOCOMOTIVE.

The development of a Self-Cleaning Front End for the E Class or Atlantic Type Locomotive.

Conclusions and Recommendations on page 52.

INTRODUCTION.

1. In this bulletin is described the development of a self-cleaning front end for our Atlantic Type locomotive, and a comparison is made of some forms of front ends on our Consolidation locomotives. The results of the experiments lead us to believe that satisfactory self-cleaning front end arrangements have been found which will increase the capacity of these locomotives for sustained runs without decreasing their efficiency.

2. Our locomotive smokeboxes retain a large part of the cinders entering them from the tubes, and provision is made for cleaning them at terminals or at coaling points on the division. This regular cleaning out of the accumulated cinders is an expensive and troublesome operation, but a greater objection to the retention of cinders in the smokebox, is the fact that they fill the passage through which the gases are drawn, and interfere with the draft. Eventually, in many cases, the passages are so closed up that the locomotive fails entirely.

3. It has seemed desirable to remove these conditions, which limit the steaming of the locomotive, and various devices have been tried, the object of which is to cause all of the cinders to be discharged from the stack. The method of producing this self-cleaning effect, is to create, in the smokebox, a restricted opening, through which the cinders are drawn

in a rapidly moving stream of gases. If the passages in the smokebox are large, the flow of gases is too slow to carry along the cinders.

4. At the same time that the narrow passage is provided, the other parts in the smokebox must be adjusted so that the whole internal arrangement of the smokebox will act as a unit in creating sufficient draft upon the fire and in discharging the cinders.

5. This bulletin describes a series of experiments with locomotives of the E class, or Atlantic Type, and H6b class or consolidation type in developing smokebox arrangements that would be self-cleaning, and at the same time give good results in steaming.

6. Satisfactory results were finally attained for the E class with an arrangement as shown in Fig. 19 and for the H6b class in Fig. 25. The development of the E class front end will be the first described.

Description of Standard Front End.

7. The front end or smokebox arrangement now in use on a large number of our Atlantic Type passenger locomotives of the E class, is shown in Fig. 2. The outside stack is 16 inches in diameter at the base and has a taper of one inch diameter per foot of height. The inside stack is not tapered. The diaphragm plate is perforated and has an adjustable plate on the lower edge, a netting covering the perforations.

8. This arrangement will be referred to in the report as the standard front end.

9. A large number of tests of various kinds have been made, on the Testing Plant, with class E2a locomotive 5266 equipped with this standard front end, and while it has been found to be a very good arrangement, when it is frequently cleaned, so far as the steaming of the locomotive is concerned. It is not self-cleaning, and with friable coals, the accumulation of cinders in the front end may be as much as 1000 pounds per hour—a quantity that seriously interferes with the draft and necessitates cleaning of the front end at the end of an hour's run. With gas coals, the accumulation of cinders

is not so serious a matter, but even with these coals 300 pounds per hour or more may be collected and the smokebox must be cleaned at the end of each trip, where the locomotive

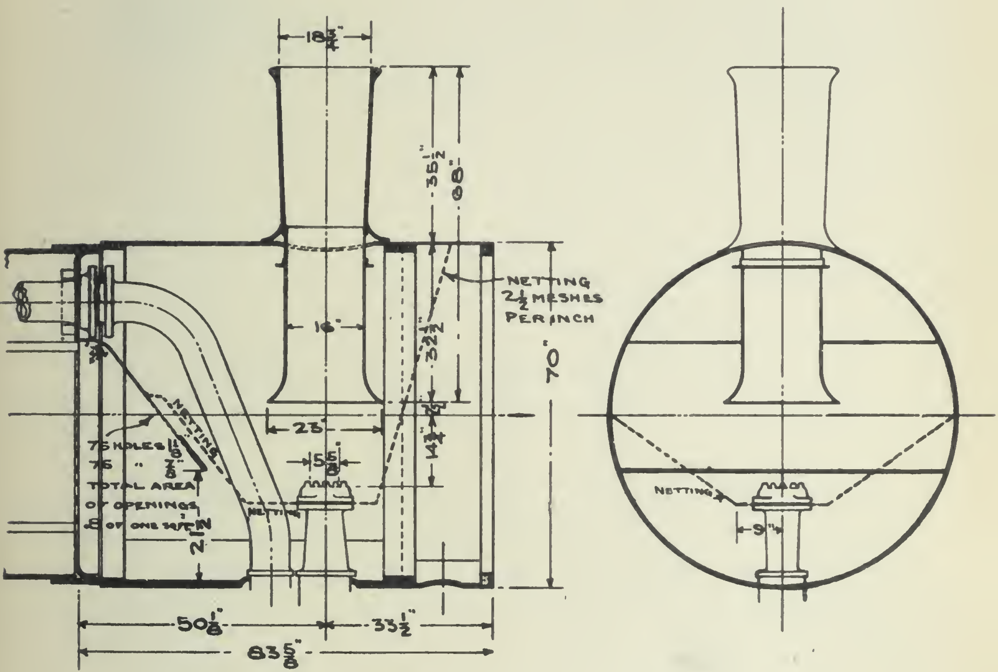


Fig. 2.

Standard front end arrangement E2a class locomotive. This form is not self-cleaning. A cinder trap is used with it. The diaphragm plate has 76 holes 1⅛ in. diameter and 75 holes ⅞ in. diameter. Its lower edge is adjustable. The part extending forward across the nozzle is made up of netting.

is working up to its capacity, and burned front ends result if there is any air leakage after cinders have collected.

Master Mechanics' Association Front End.

10. A committee, appointed by the American Railway Master Mechanics' Association, reported upon a series of front end tests that were made at Purdue University, with a

New York Central & Hudson River Railroad locomotive of the 4-4-2, or Atlantic Type (See Proceedings, American Railway Master Mechanics' Association, Volume XXXIX, 1906). Conclusions from these tests for a front end arrangement for best results, are given in the report as follows:

"A suggestion as to a standard front end is presented as Fig. 1, which, with the following equations referring thereto, may be accepted as a summary of conclusions to be drawn from all experiments made.

"For best results make H and h as great as practicable. Also make

$d = 0.21\ D + 0.16\ h.$
$b = 2d$ or $0.5\ D.$
$P = 0.32\ D.$
$p = 0.22\ D.$
$L =$ (Not well established) $= 0.6\ D$ or $0.9\ D$ but not of intermediate values."

11. These rules were used as the basis of a design of front end arrangement to be tried. No attempt was made, however, to have the lengths of the smokebox conform to those recommended, which could make it either 63 inches or 42 inches in length instead of the present 83⅝ inches for the E class locomotive.

12. In Fig. 1 the proportions of the front ends as finally developed, and which gave the best results on our locomotives, are shown in connection with the Master Mechanics' recommendations, for a best arrangement.

13. Our arrangements do not conform very closely to the Master Mechanics. One difference is in the length of inside stack (P). This length had to be increased in order to lift the cinders from the table plate or diaphragm. The longer inside stack, limits the diameter of bell (b), on account of the smaller space available near the top of the exhaust nozzle. The bell should not be circular, but should be extended on the sides to more completely cover the horizontal part of the plate. In these experiments, however, the bell was circular.

M. P. 479—A

8 x 10½

LOCOMOTIVE:
TYPE [redacted]
CLASS [redacted] NO. [redacted]

PENNSYLVANIA RAILROAD COMPANY
PHILADELPHIA BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

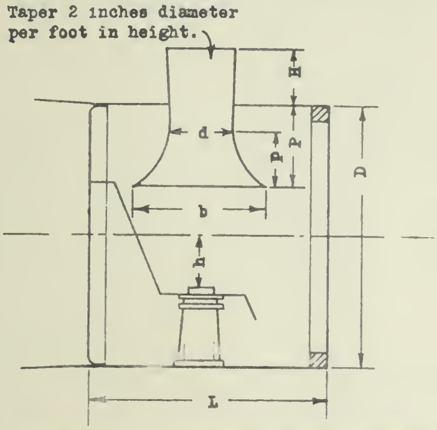
TEST DEPARTMENT

SHEET NO. P-353

Bulletin No. 9

Self Cleaning Front End

ALTOONA, PA 8-30-1912



ARRANGEMENT OF FRONT END FOR BEST RESULTS

		Master Mechanics Association	E2a & E3a Classes	H6b Class
Stack throat	d	0.21 D + 0.16 h	0.21 D + 0.09 h	0.21 D +0.87 h
" bell	b	2 d or 0.5 D	1.44 d or 0.33 D	1.32 d or 0.304 D
Length of inside stack	P	0.32 D	0.54 D	0.51 D
Length of bell	p	0.22 D	Not established	Not established
Length of Smokebox	L	Not well established 0.6 D or 0.9 D but not of intermediate values.	1.19 D	0.9 D

h - Tip of nozzle to center line of smokebox.
D - Diameter of smokebox.
H - Height of outside stack.

SHEET NO. P-353

Fig. 1.

Diagram of front end arrangement giving best results as shown in report of Master Mechanics' Association tests.

The Locomotive on Which the Tests Were Made.

14. An E2a class locomotive 5266, was used for most of the front end trials but later some of the devices were applied to E3a class locomotive 2984. An outline drawing of these classes is shown in Fig. 3 and the principal dimensions of the locomotives are given in Tables 3 and 7. The E3a locomotive differs from the E2a in diameter of cylinder only.

Draft and Back Pressure.

15. In the tests made by the Master Mechanics' Committee, oil was used for fuel and by its use the admission of air to the firebox could be completely controlled. With oil firing, the effectiveness of any arrangement could be derived from the draft indications; the draft in the smokebox at any fixed back pressure being dependent only upon the smokebox arrangement.

16. As our problem was to devise an arrangement that would clear the smokebox of cinders, the use of oil for fuel could not be considered, and with coal it was found impossible to duplicate draft readings under apparently similar conditions of running.

17. By means of a steam engine indicator connected to the exhaust pipe, a few inches below the nozzle, the back pressure was observed, and by running the locomotive under gradually increasing loads, a series of readings of the back pressure and corresponding draft or vacuum in the smokebox was obtained. These readings are plotted in Fig. 4, showing results for a light or thin fire on the grate. Fig. 5 shows a series of readings under similar conditions but with a heavy fire on the grate. A comparison of these diagrams indicates very clearly that the draft is so closely dependent upon the thickness of the fire that it cannot be used as a basis of comparison for different front end arrangements when firing coal.

18. In Fig. 6 the same readings of draft are shown in relation to the draft in front of the diaphragm. Here again the differences in draft conditions due to thickness of the fire are evident.

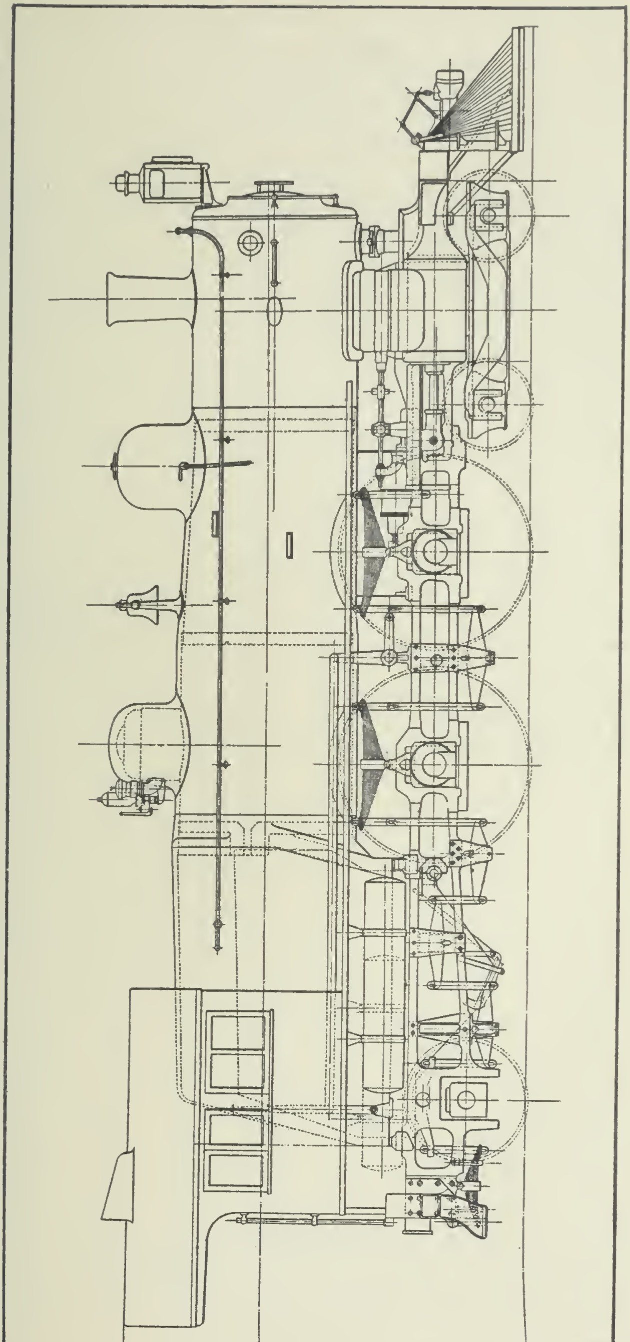


Fig. 3.
GENERAL ARRANGEMENT OF E2a AND E3a CLASS LOCOMOTIVE.

LEADING DIMENSIONS OF LOCOMOTIVE (E2a CLASS)

Total weight in working order, pounds	184,167
Weight on drivers, in working order, pounds	110,000
Cylinder (simple) size, inches	20½ x 26
Diameter of driving wheels, inches	80
Firebox heating surface, square feet	156.86
Heating surface of tubes (water side), square feet	2,471.04
Total heating surface (based on water side tubes), square feet	2,627.90
Total heating surface (based on fire side tubes), square feet	2,319.26
Grate area, square feet	55.5
Boiler pressure, pounds per square inch	205
Valves, type	Wilson double ported, slide
Valve gear	Stephenson
Firebox type	Wide, Belpaire
Number of tubes	315
Outside diameter of tubes, inches	2
Length of tubes, inches	180

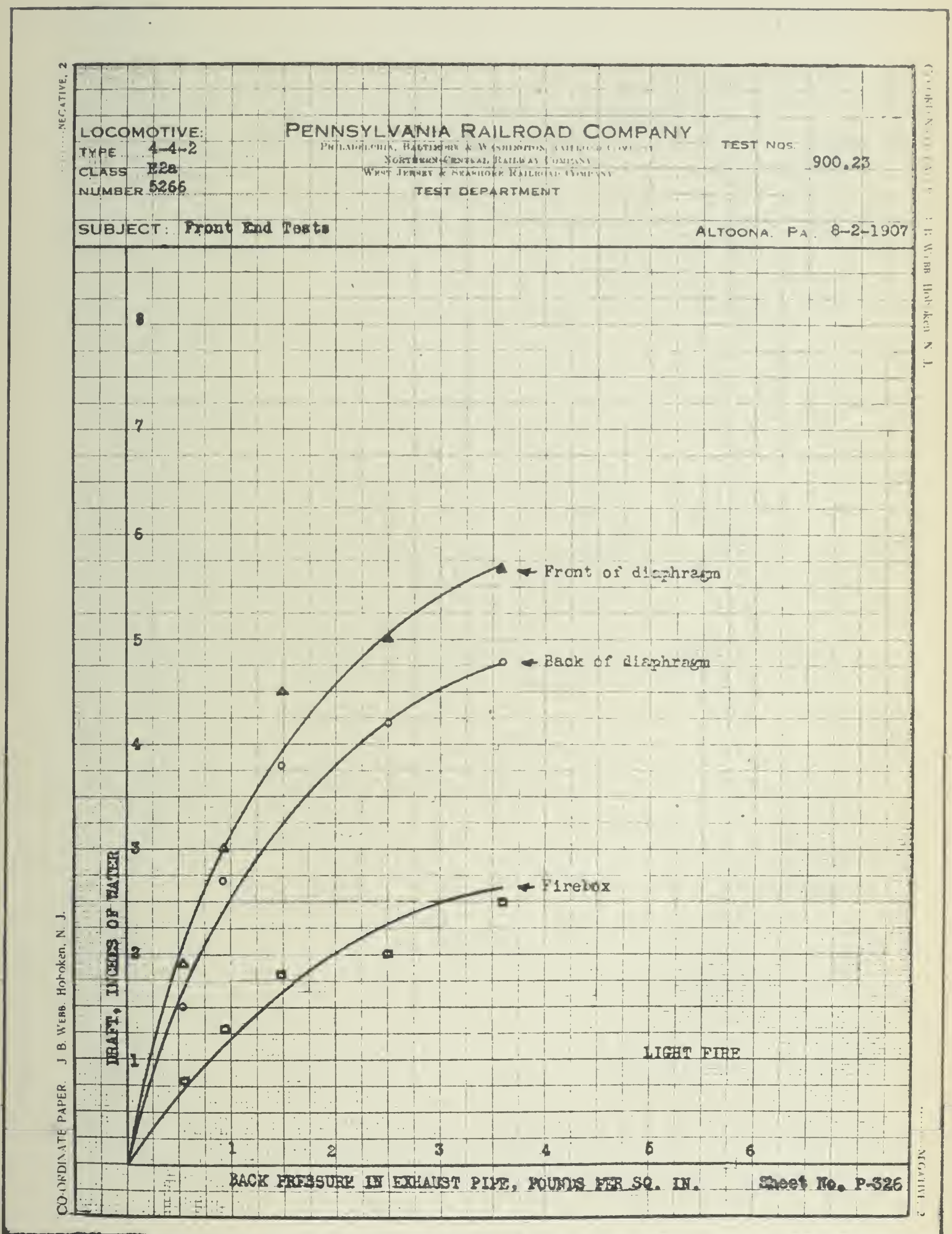


Fig. 4.

The draft in the smokebox and firebox with a thin or light fire.

19. With a light fire the loss in draft between the two sides of the diaphragm and between the front of diaphragm and the firebox decreases uniformly as the intensity of the draft increases.

20. With a thick fire the losses first increase to a maximum at about five inches of draft and then decrease with higher draft.

21. In estimating the comparative merits of the different devices tried, it then became necessary to take account of a number of factors, as:

The weight of cinders collected in the smokebox.

The quantity of water that could be evaporated as compared with the standard front end.

The evaporation per pound of coal, or the efficiency of the boiler.

The general steaming of the locomotive as shown by the boiler pressure during a test.

22. These methods, although logical, may appear to be indefinite and unscientific. There is at present no rational method for smokebox design and until much more careful investigations are made, comparisons of different smokebox arrangements cannot be based upon anything but very general considerations.

23. It would have added greatly to the value of the tests if the weight of sparks discharged could have been measured. At the time of the tests, however, apparatus for this purpose had not been perfected, and the cinders remaining in the smokebox were all that could be weighed.

24. From tests made with the standard front end it was known that the boiler could be expected to give an equivalent evaporation of about 16 pounds of water per square foot of heating surface, with Scalp Level coal, and 18 pounds with Penn Gas coal. To obtain the lower evaporation, a speed of 160 revolutions per minute and a cut-off of 27 per cent. was required with locomotive 5266 with fully open throttle, and for the higher evaporation of 18 pounds, 160 revolutions and 32 per cent. cut-off with full throttle.

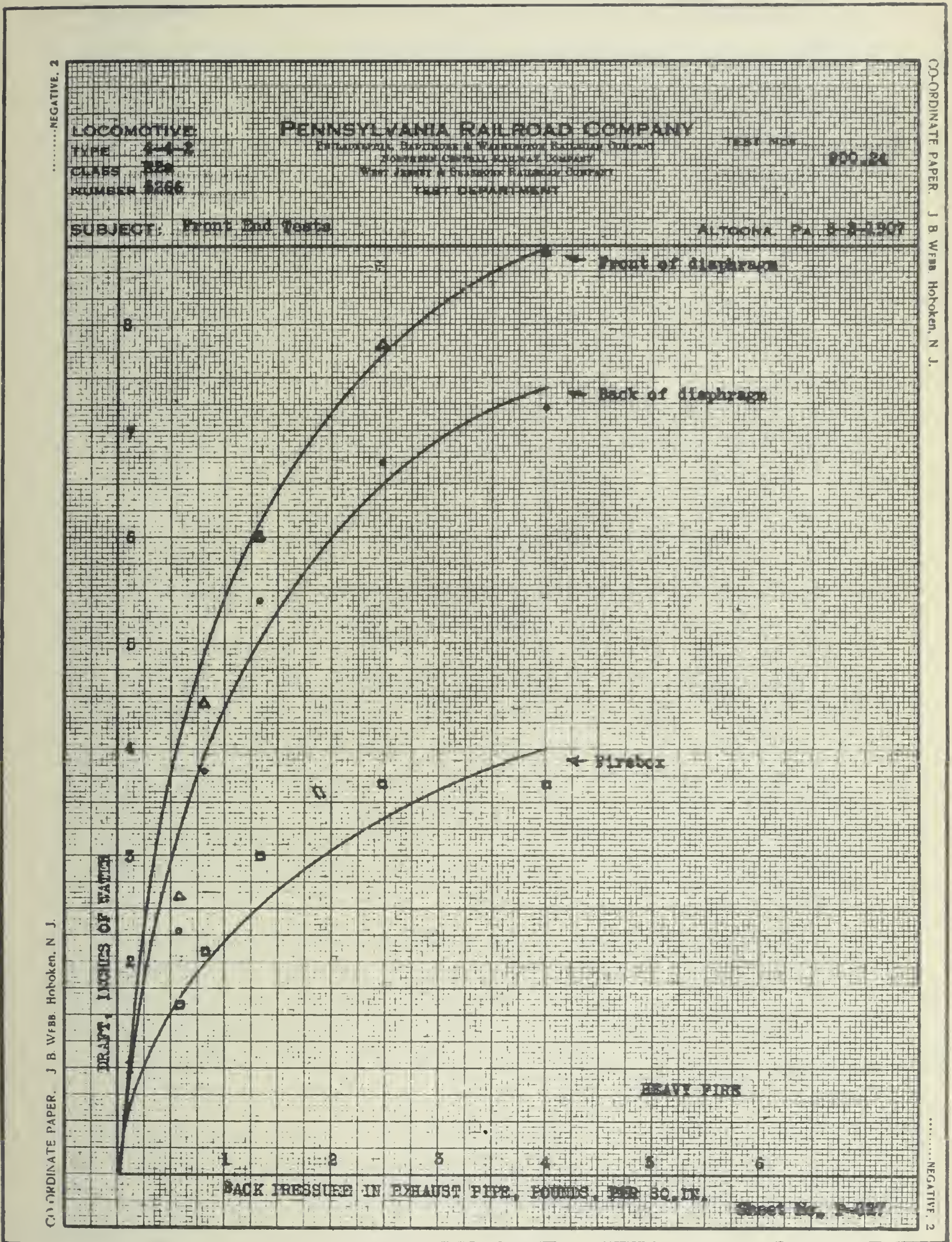


Fig. 5.

The draft in the smokebox and firebox with a thick or heavy fire. The draft is nearly two times what it was with a thin fire.

25. If the results with the standard front end could be equalled with a self-cleaning device the object of the tests would be accomplished, as, with the added advantage of a self-cleaning front, which would permit the use of friable coal, the capacity of the locomotive would not be reduced.

26. The tests were made with both Scalp Level and screened Penn Gas coals. The Scalp Level coal was used for the preliminary runs, as with it large quantities of cinders are drawn through the tubes and the self-cleaning feature could be better observed than with a coal making less cinders.

27. The final series of tests was made with Penn Gas coal as it is one of the regular passenger coals, while Scalp Level is not.

28. The same fireman fired all of the tests on locomotive 5266, with one exception, which will be noted later.

The Tests.

The Effect of a Movement of the Diaphragm Edge with the Standard Front End.

29. Before any changes were made in the standard front end, Fig. 2, some trials were made to note the effect on the fire of a movement of the lower edge of the diaphragm plate. The normal position of this edge for locomotive 5266 is as shown, 21½ inches above the bottom of the smokebox. The plate was lowered 5½ inches from this normal position and after a short trial run it was raised 5¼ inches above the normal position and a trial made.

30. These changes in the position of the diaphragm plate over a range of 10¾ inches, produced no marked effect upon the burning of the fire. It burned evenly over the whole grate under each adjustment of the diaphragm, and the locomotive steamed as freely with the plate in either the upper or the lower positions as it did under normal conditions.

31. The fact that the diaphragm is perforated may account for the lack of sensitiveness or marked effect upon the fire when the plate is given a new position.

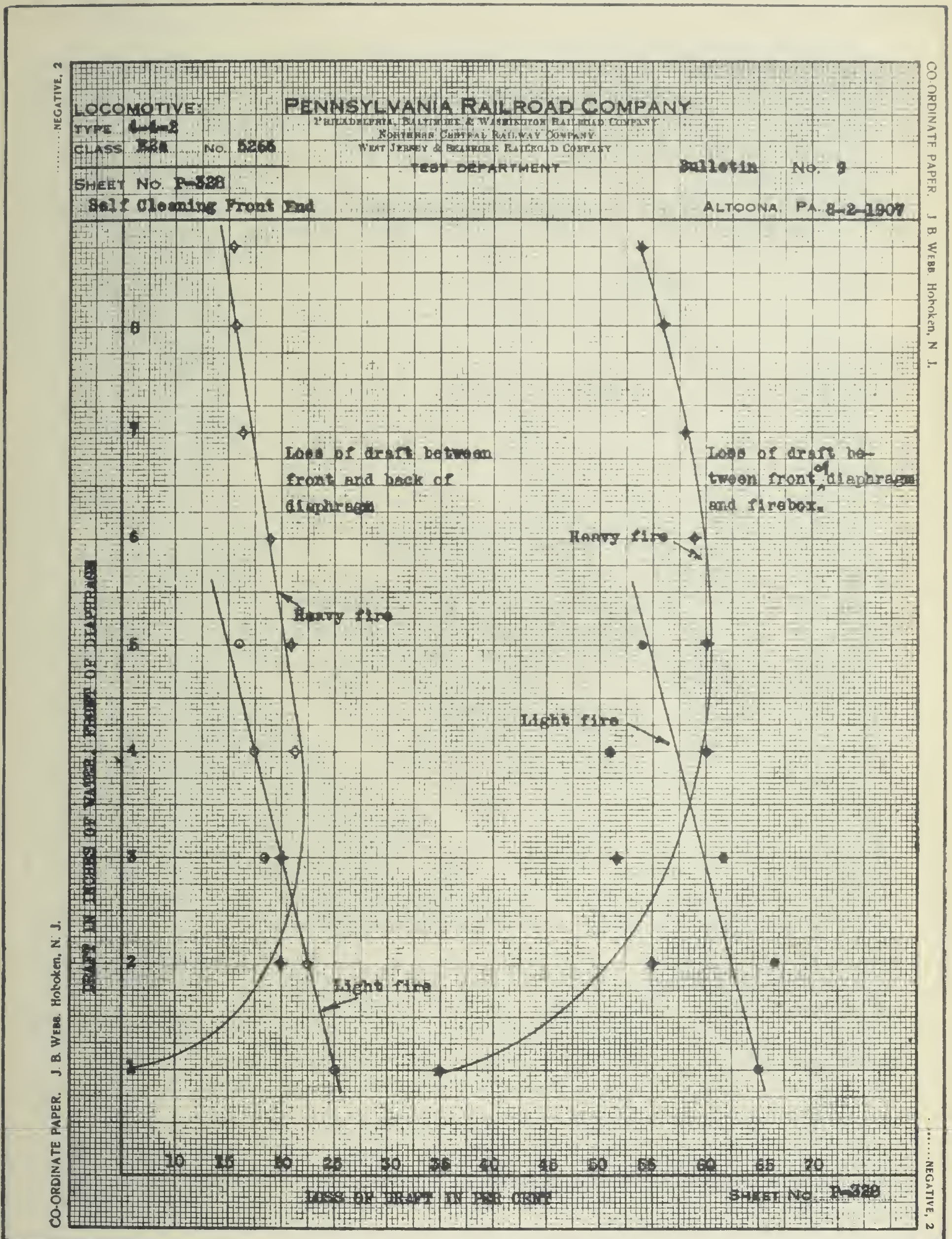


Fig. 6.

Draft losses at different rates of combustion with a thick and a thin fire. The loss in draft increases to a maximum, and then decreases with a thick fire. With the thin fire the losses become less as the draft is increased.

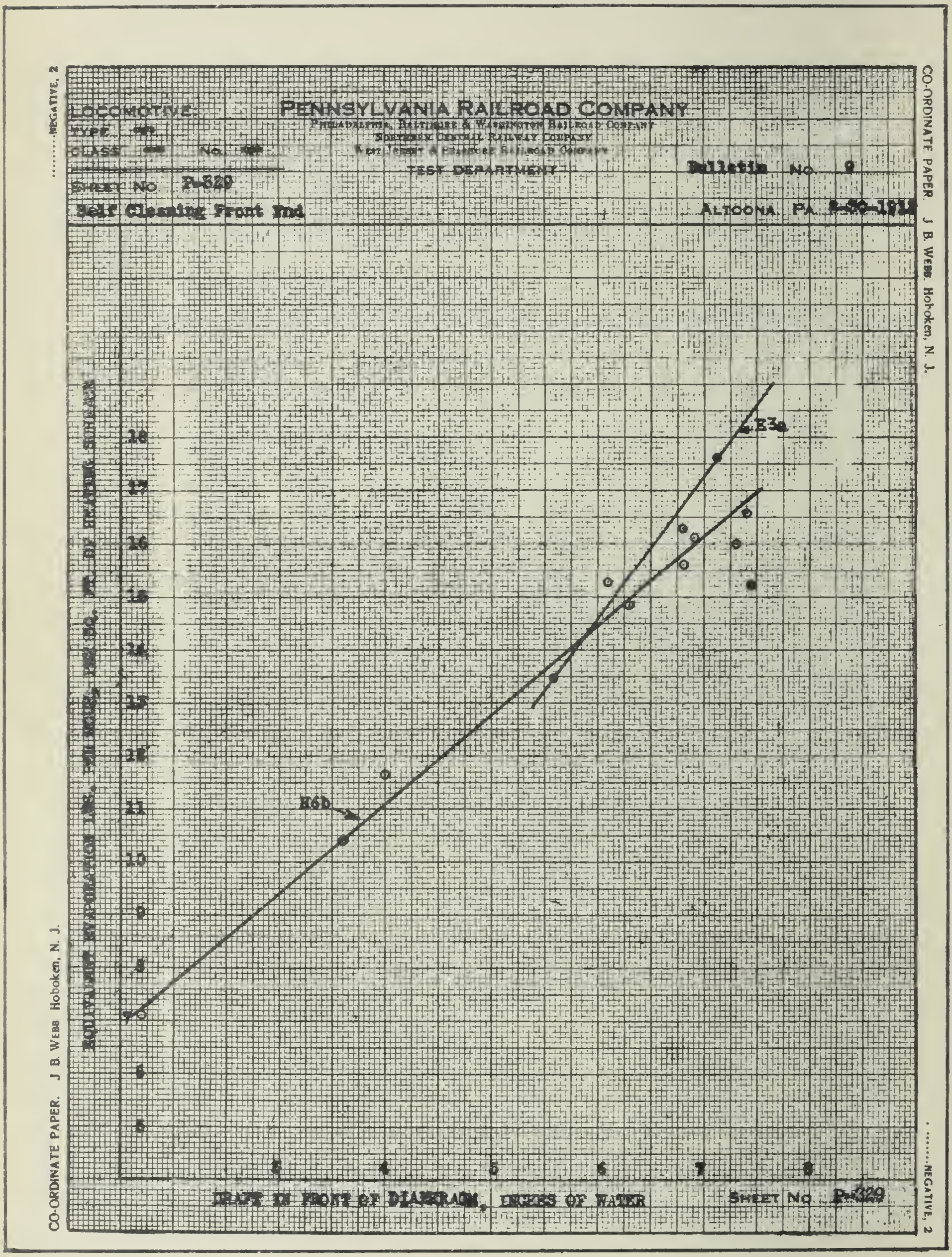


Fig. 7.

A comparison of draft and evaporation for the best arrangement on the E class and the H6b class. The rates of evaporation for the two classes are very nearly alike.

Preliminary Tests.

32. The trials of front end made by the Master Mechanics' Committee did not determine the arrangement of the diaphragm plate to make the smokebox self-cleaning, and the first consideration in these tests was to investigate the shape of the diaphragm and its location in the smokebox for this purpose.

33. A diaphragm of the general type recommended by the Committee as applied to this locomotive is shown in Fig. 8. The whole diaphragm plate was without perforation, and, as first applied, extended beyond the centre line of the nozzle a distance of $16\frac{3}{4}$ inches. At its end there was an angle and a plate $4\frac{1}{4}$ inches wide, extending downward to a point $13\frac{1}{4}$ inches above the bottom of the smokebox. The netting was omitted for these preliminary trials.

34. With the arrangement as described above and as shown in Fig. 8 a test was made, No. 900.25, using Scalp Level coal and working the boiler at about the limit of its capacity to maintain a good pressure. The arrangement was found to be perfectly self-cleaning, there being no cinders at all left in the bottom of the smokebox.

35. An inside stack, according to the Master Mechanics' recommendations, was then applied as shown in Fig. 9, and without other changes, a test, No. 900.26, was made at the same speed and cut-off as before.

36. The exhaust nozzle was then changed from $5\frac{5}{8}$ inches diameter to $5\frac{7}{8}$ inches diameter, but after a few minutes of running, with this large nozzle it was evident, on account of the falling pressure, that the nozzle was too large to give sufficient draft.

37. The nozzle was then reduced to $5\frac{3}{4}$ inches diameter, and without other changes a test was made at a lower rate of evaporation than the earlier tests.

38. This arrangement, Fig. 9, was found to steam fairly well and to be perfectly self-cleaning.

39. The smokebox was then fitted with a stack that was exactly according to the Master Mechanics' recommendations.

In tests Nos. 900.26, 900.27 and 900.28 the inside stack only had conformed to these recommendations. With this Master Mechanics' stack, which is shown in Fig. 10, tests with 5¾-inch and 5⅞-inch exhaust nozzle were made, tests Nos. 900.29, 900.30 and 900.31. In these tests it was observed that while the cinders were all blown out of the front end there appeared to be a higher velocity of the gases through the restricted passage under the edge of the diaphragm, than would be necessary for this purpose, or there was a large difference between the draft front and back of the diaphragm, indicating that too great a resistance to the passage of the gases was caused by the length of the diaphragm plate.

40. The plate was then cut off until it extended but 7½ inches in front of the exhaust nozzle centre.

41. Tests Nos. 900.32, 900.33 and 900.34 were then run and in the table below the resulting draft readings are given.

Table 1.

Draft in Front End—Scalp Level Coal.

Test No.	Test Designation			Front End Arrangement	Draft in Smokebox Inches of Water		Difference between F and B in Per Cent.	Diameter of Exhaust Nozzle	Back Pressure in Exhaust Pipe, Pounds per Square inch.	Cinders Collected in Smokebox, Pounds per Hour.
	M. P. H.	Cut-off	Throttle		Front of Diaphragm F	Back of Diaphragm B				
900.25	37.65	27	Full	Fig. 8	4.9	3.2	34.7	5⅝	4.6	0
900.26	37.65	27	Full	Fig. 6	4.8	3.3	37.5	5⅝	4.9	0
900.30	37.65	27	Full	Fig. 10	5.3	3.7	30.1	5¾	3.4	0
900.31	37.65	27	Full	Fig. 10	4.8	3.4	29.1	5⅞	2.4	0
900.32	37.65	27	Full	Fig. 10	5.2	4.3	17.3	5¾	4/6	48
900.34	37.65	27	Full	Fig. 10	5.0	4.3	16.0	5⅞	No record	No record
917	37.65	27	Full	Fig. 2	7.7	6.2	19.5	5⅝	No record	492

Tests 900.30 and 900.31 had the table plate extended 16½ in. ahead of the exhaust nozzle centre, while 900.32 and 900.34 had the plate 7¾ in. ahead of the nozzle.

42. While, in general, as has been explained, the draft indications can not be depended upon as comparative, it appears from these figures that when the diaphragm plate was shortened, just before test No. 900.32, that there was a

marked decrease in the difference between the draft front and back of the diaphragm, and that the effective draft, or the draft back of the diaphragm was increased.

43. Test No. 917 was with the same kind of coal as the others (Scalp Level), but with the old form or standard front end, Fig. 2.

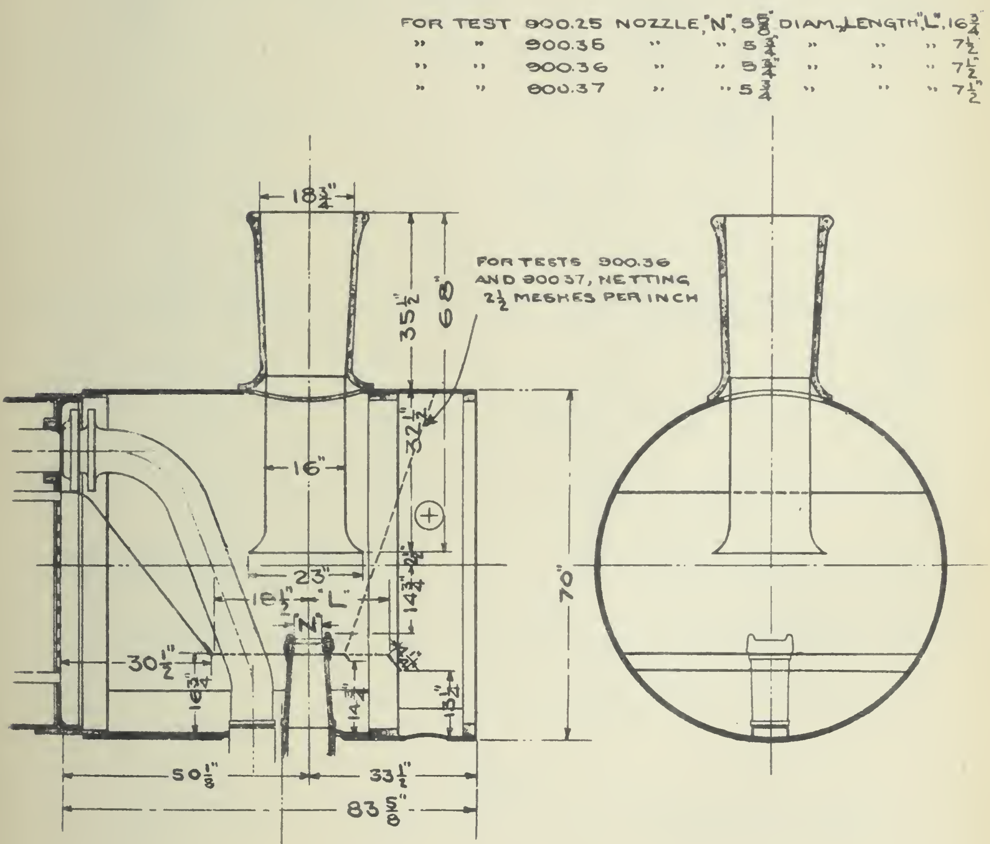


Fig. 8.

In this arrangement the diaphragm plate extends across the nozzle, and 16¾ inches ahead of it. After one test the plate was shortened to 7½ inches ahead of the nozzle.

44. In test No. 900.32 there were 48 pounds of cinders in the smokebox, indicating that the plate was now as short as it could be made for self-cleaning.

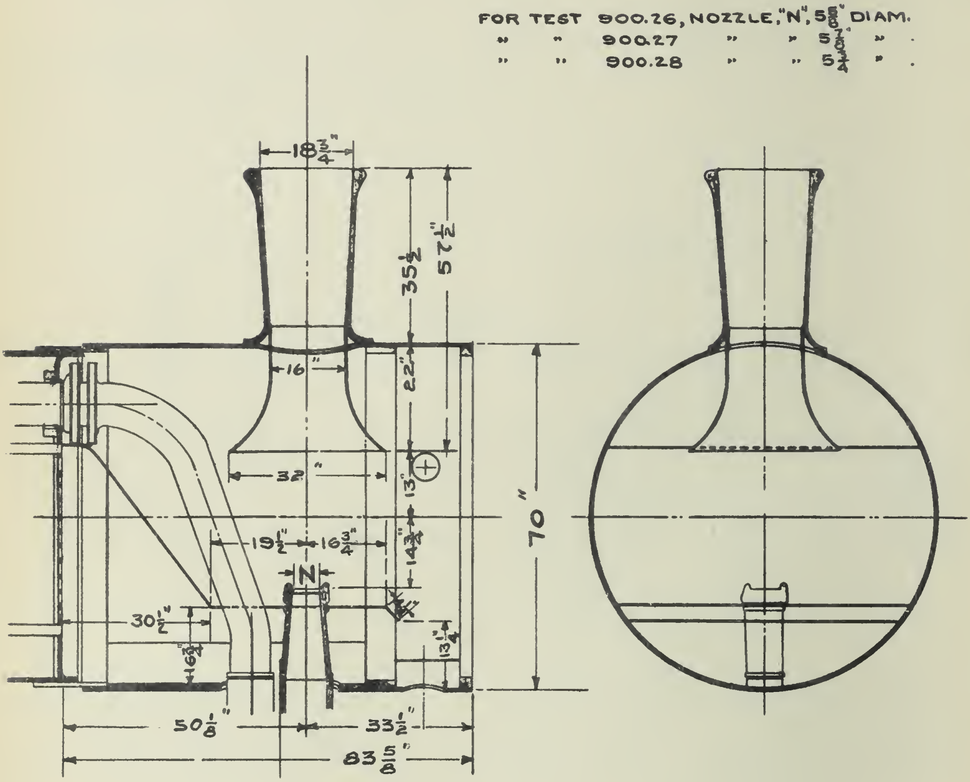


Fig. 9.

A new form of inside stack is applied. The long diaphragm plate is retained here. Three diameters of nozzle were used.

45. The smokebox arrangement was then made as shown in Fig. 8, the standard outside and inside stack being substituted for the Master Mechanics' form. A netting was put in with this arrangement.

46. Up to this time the netting had been omitted so as to simplify operations in making changes in the front end arrangement. It was assumed that the netting would have no effect upon the action of the front end, except to break up the large sparks, and this was confirmed later when the netting was applied.

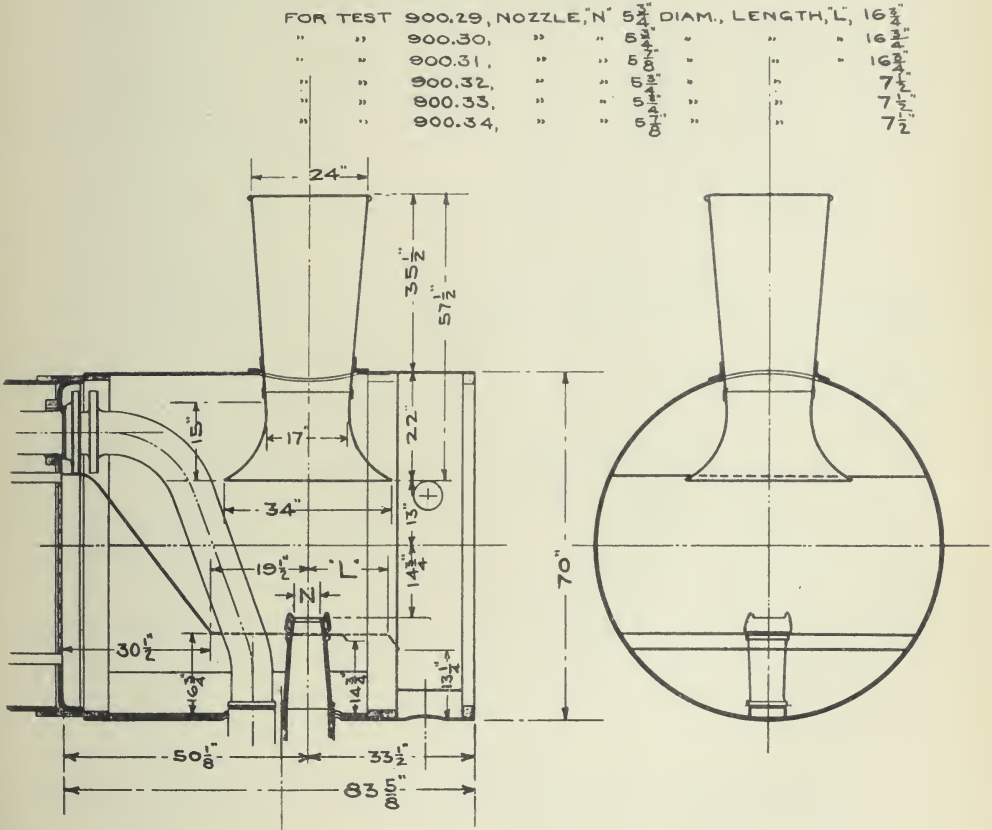


Fig. 10.

This shows the Master Mechanics' stack complete. Two lengths of diaphragm and two diameters of nozzle were used.

47. After making two tests, Nos. 900.36 and 900.37, with this arrangement the diaphragm plate was raised in the

smokebox as shown in Fig. 11, the exhaust nozzle being lengthened to suit the new height of diaphragm. At the front edge the plate measured 20½ inches above the bottom of the smokebox. With the diaphragm in this position the loco-

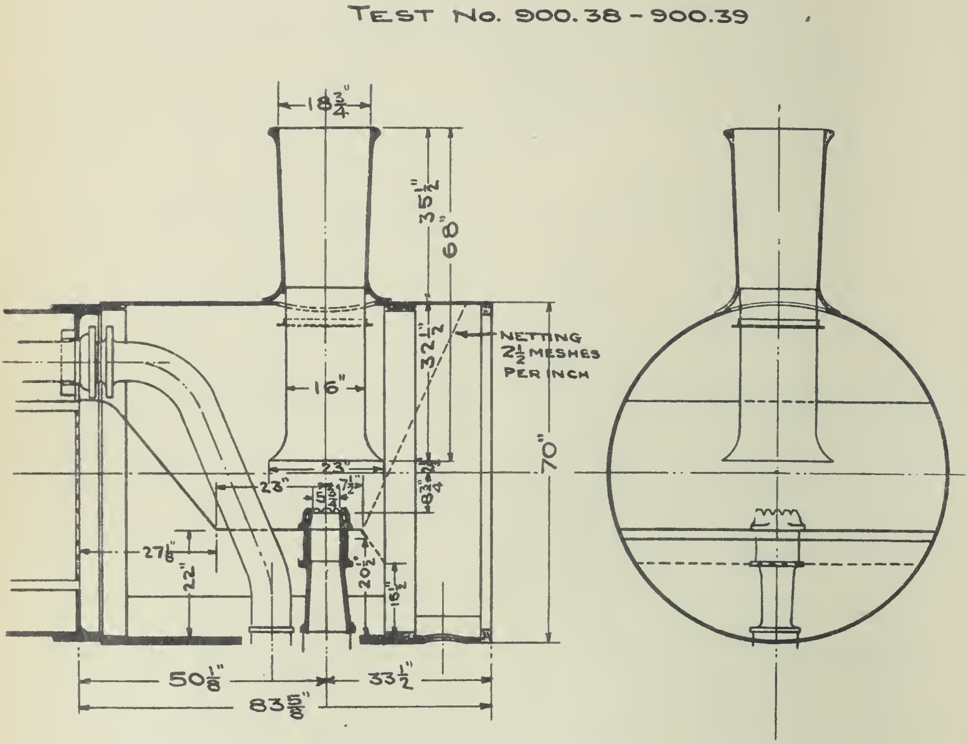


Fig. 11.
The standard stack has been returned to place, and the exhaust pipe lengthened.

motive steamed well—test No. 900.38—but there were 225 pounds of cinders collected in the smokebox per hour.

48. Without moving the main diaphragm plate, an inclined plate was fitted to its forward edge. This plate extended down to a point 15½ inches above the bottom of the smokebox. The area of opening for the passage of gases was then about

the same as in the arrangement shown in Fig. 8 and it was expected that the results would be the same as with the whole diaphragm in the lower position, but from the test, No. 900.39, with this design it is evident that the two arrangements, while giving the same area for the passage of gases, are by no means alike, as in test No. 900.39, the locomotive did not steam well and there were 76 pounds of cinders collected in the smokebox.

49. It would appear, then, that when changes are made in the height of diaphragm the whole plate should be raised and not the forward edge alone.

50. The plate without the movable deflector, presents, for the flow of gases, a passage free from obstructions or abrupt changes of form, and it is probable that this will account for the better results had with it than with the plate set high in the smokebox but having the movable edge plate.

51. Following still further the idea of making a smooth and direct passage for the gases to the stack, the arrangement shown in Fig. 12 was applied. This consists of a conical pipe from the tube sheet carried forward and turning upward and connecting at its smaller end directly to the stack.

52. The exhaust nozzle for this arrangement was made with a flared tip so that it would act as an expanding nozzle to convert the pressure energy of the steam into velocity, without loss, in that way obtaining an efficient exhaust jet.

53. Test No. 900.40 was made with this apparatus. It was very effective in discharging cinders, but the nozzle was found to be too large to make the locomotive steam. The sparks discharged from the stack were at a red heat and to break up these, and reduce their temperature, a netting was put in the pipe back of the exhaust nozzle and the nozzle reduced in diameter. The netting could not be very large in area on account of the limited space, and it was found that the area of the openings through it was too small for practical purposes.

54. Nothing further was done with this arrangement as it was not considered of value if a netting could not be used in it.

55. A diverging or flared tip nozzle was again tried with

the arrangement shown in Fig. 13. The smallest diameter of this nozzle was 5¾ inches, with a taper to the top of about one in six. The locomotive did not steam well with this nozzle, though the back pressure below the nozzle was reduced,

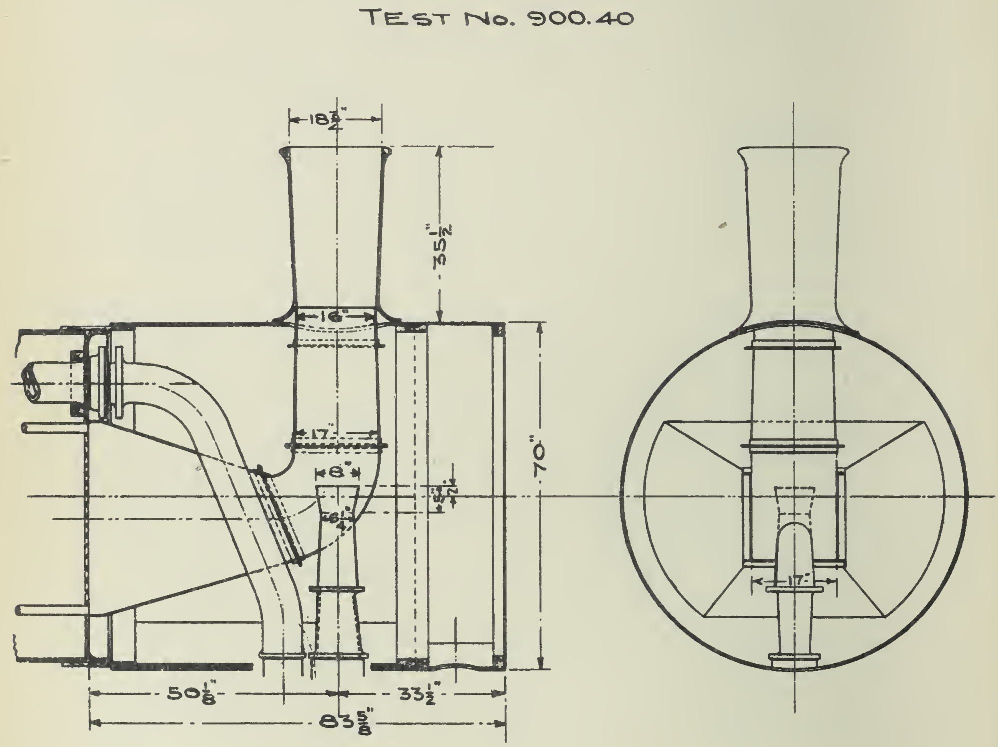


Fig. 12.
This is a tapered connection between the tubes and stack. It did not give satisfactory results.

test 900.47. With the straight nozzle, the back pressure was five pounds per square inch while with the tapered nozzle it was two pounds.

56. To make the locomotive steam it would have been necessary to further reduce the nozzle diameter, but as it was then as small as the straight nozzle it was not reduced and no further trials of it were made.

Final Tests.

57. After the preliminary trials of the various devices that have been described, three of those which were of greatest promise were selected for further tests. These arrangements are shown in Figs. 14, 15 and 16.

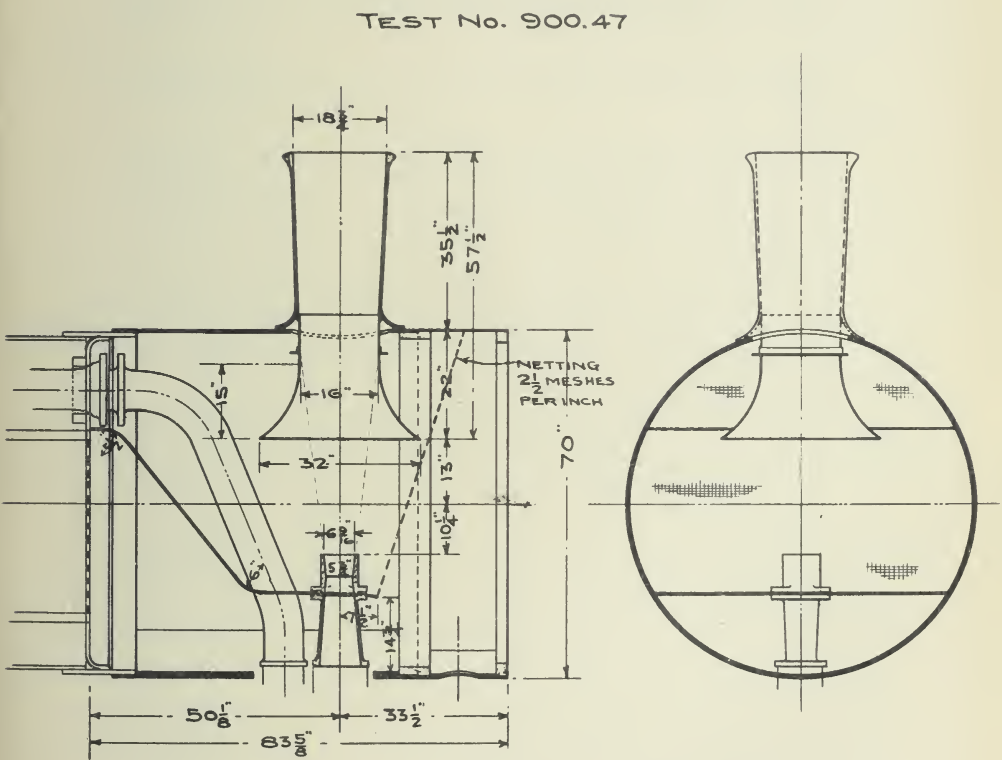


Fig. 13.
An expanding nozzle and the Master Mechanics' inside stack.

58. Fig. 14 shows the front end recommended by the Master Mechanics' Association as applied to the E class locomotive. It has a tapered stack with a wide-mouthed inside

stack. The diaphragm plate is without perforations and is carried down and forward to a point $7\frac{1}{2}$ inches in front of the exhaust nozzle centre. The edge of the plate is at a point $14\frac{3}{4}$ inches above the bottom of the smokebox and the area of the passage for the gases at this restricted point is three-fourths of the area of the tube opening or fire area.

59. The tests with these three arrangements were each of two hours duration at 160 revolutions per minute, or about 36 miles per hour. Tests Nos. 900.41 to 900.44 were run at the same cut-off with full throttle. Penn Gas coal was used for all.

60. The results of these tests are given in the Tables 6 and 8.

61. Good results were obtained with each of these arrangements. They were all perfectly self-cleaning except for a slight accumulation of cinders on the horizontal plate of the diaphragm.

62. There was some difficulty in keeping up the steam with the arrangement Fig. 14, test No. 900.41, but it will be noted that the boiler horse-power in this test was higher than for the others.

63. Test No. 900.44, with arrangement Fig. 16, shows a better evaporation per pound of coal than any of the others and it was thought, all things considered, that this was the best arrangement.

64. Another test was then run with it to develop the maximum boiler capacity,—test No. 900.45 at 160 revolutions and 32 per cent. nominal cut-off, and this test was run without difficulty. This is as late a cut-off as can be run with the standard front end at this speed, and as with the arrangement, Fig. 16, the nozzle was $\frac{1}{8}$ inch larger in diameter than was used with the standard arrangement, it is to be presumed that the boiler capacity is as great with this self-cleaning front as with the standard, with the added advantage of slightly decreased back pressure in the cylinders due to the large nozzle.

65. After the maximum capacity test a trial was made at a very low rate of working, under partial throttle, to note the effect of such conditions on the quantity of cinders collected in

the smokebox. This test, No. 900.46, at a speed of 160 revolutions, 27 per cent. cut-off and the steam throttled to one-half the boiler pressure, shows practically no cinders collected in the smokebox.

Tests with Different Firemen.

66. To show that the results obtained with this self-cleaning

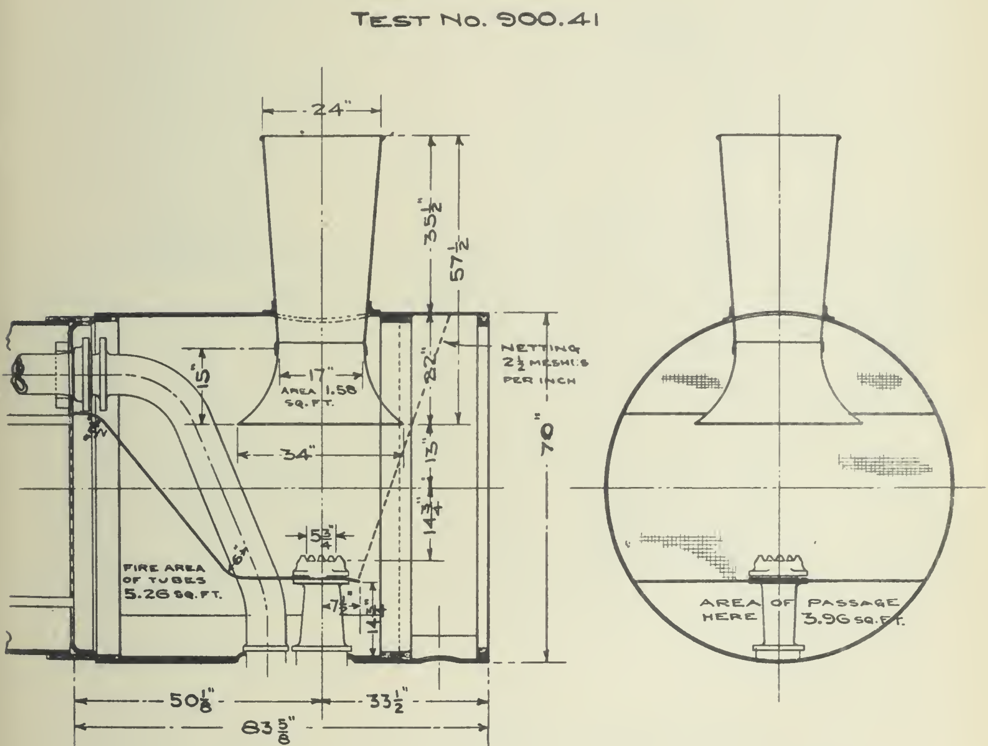


Fig. 14.
The Master Mechanics' stack. The length of front end does not conform to the Master Mechanics' recommendations.

front were not due to good firing alone, tests Nos. 900.42 and 900.43 with the arrangement shown in Fig. 15 were made under precisely the same conditions, with the exception that test No. 900.42 was fired by the regular Testing Plant fireman, while No.

900.43 was fired by an inexperienced man who had been firing but two months and had never fired this class of locomotive.

67. The results of these tests show that the good steaming of the locomotive with this self-cleaning front can be obtained by the average fireman, but they also show that the inexperienced

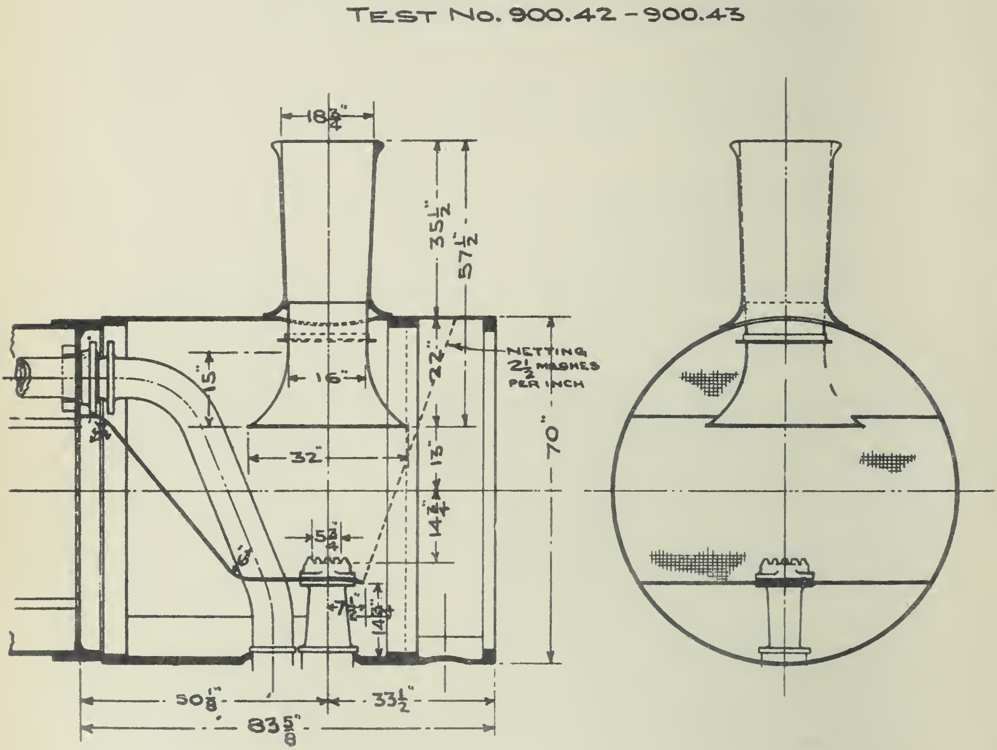


Fig. 15.
The Master Mechanics' inside stack and standard outside stack.

man may use as much as 750 pounds of coal per hour over the amount actually required.

Self-Cleaning Front E3a Class.

68. At this point, after tests which indicated that for locomotive 5266, E2a class, the self-cleaning front, Fig. 16 would give the best results, it was thought best to determine if this arrange-

ment would give equally good results if applied to another boiler of the same class. Locomotive 5266, class E2a was, therefore, removed from the plant and put into road service equipped with arrangement Fig. 16 and E3a locomotive 2984, fitted with the same arrangement, was placed on the plant.

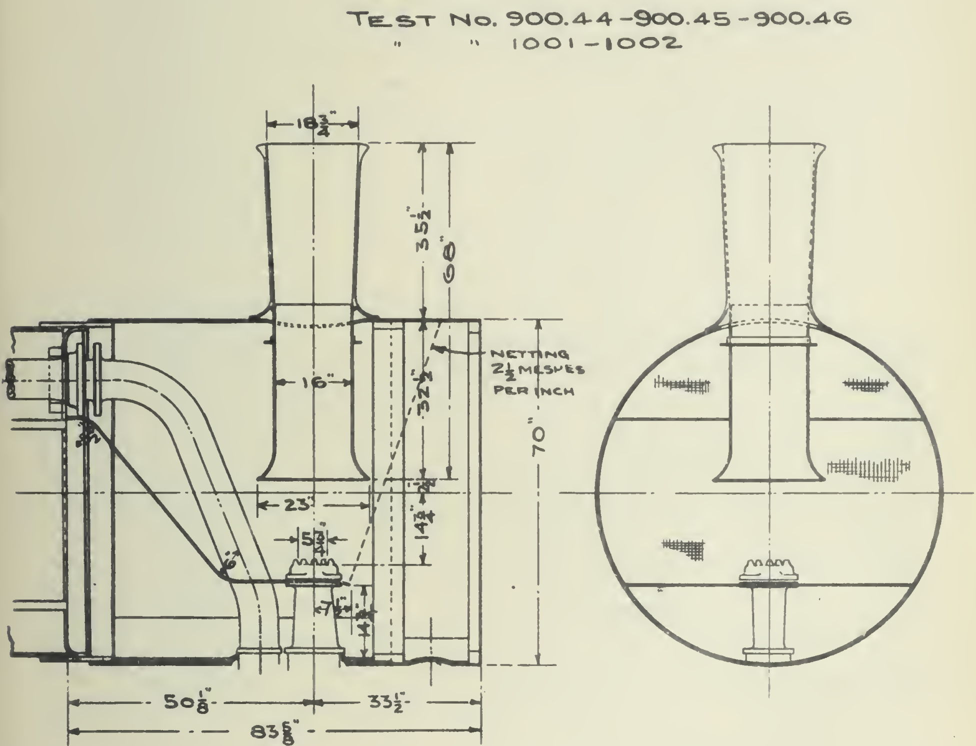


Fig. 16.

The standard stack and short form of diaphragm plate. This arrangement was satisfactory, except for cinders collecting on top of diaphragm.

69. Test No. 1001 with locomotive 2984 gave an evaporation (17.7 pounds per square foot of heating surface) that was practically the same as obtained with locomotive 5266, namely: 17.9 pounds equivalent evaporation per square foot of heating surface per hour. The locomotive steamed freely, maintaining a fairly

uniform boiler pressure and there were no cinders in the smoke-box except a small quantity on the horizontal plate of the diaphragm.

70. This test, No. 1001, did not appear to be quite up to the limit of boiler capacity, and had it been possible, the cut-off would

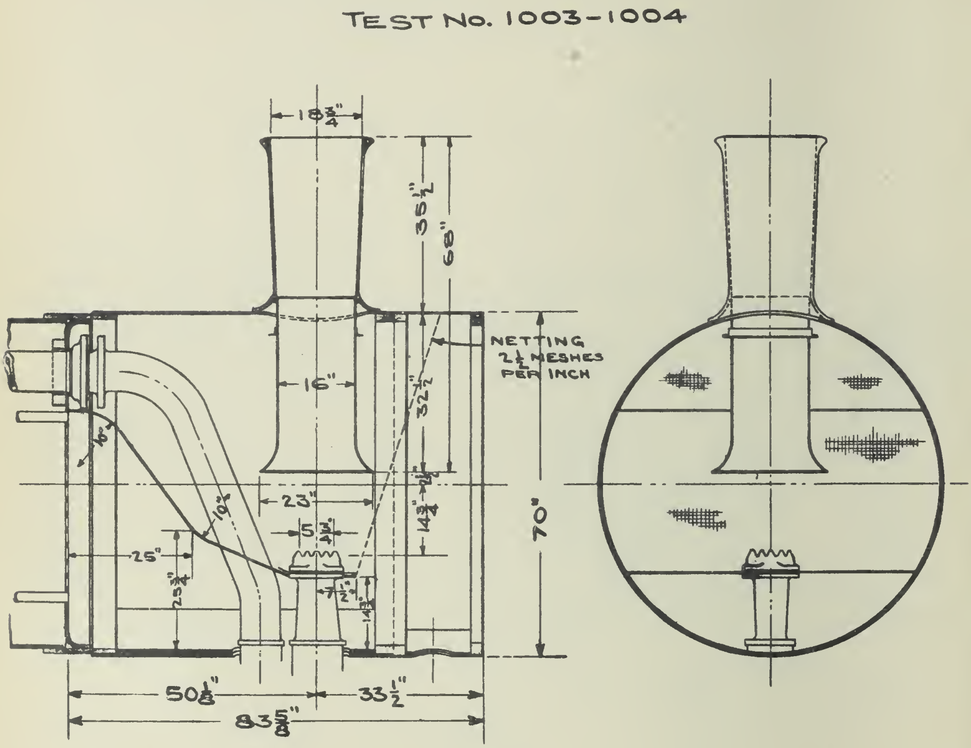


Fig. 17.
The diaphragm made sloping to remove cinders.

have been extended, but it was found for this locomotive that the friction brakes were working up to their limit and no more power could be absorbed by them.

71. Another test, No. 1003, was then made with this arrangement at slightly lower power.

72. From these two tests, though they were not quite up to

the maximum evaporation of the other locomotive, one of them was but two-tenths of a pound less per hour and it is clear that this boiler will give the same results as the other with this front end.

73. Modifications of the diaphragm were then taken up to

TEST No. 1005-1006

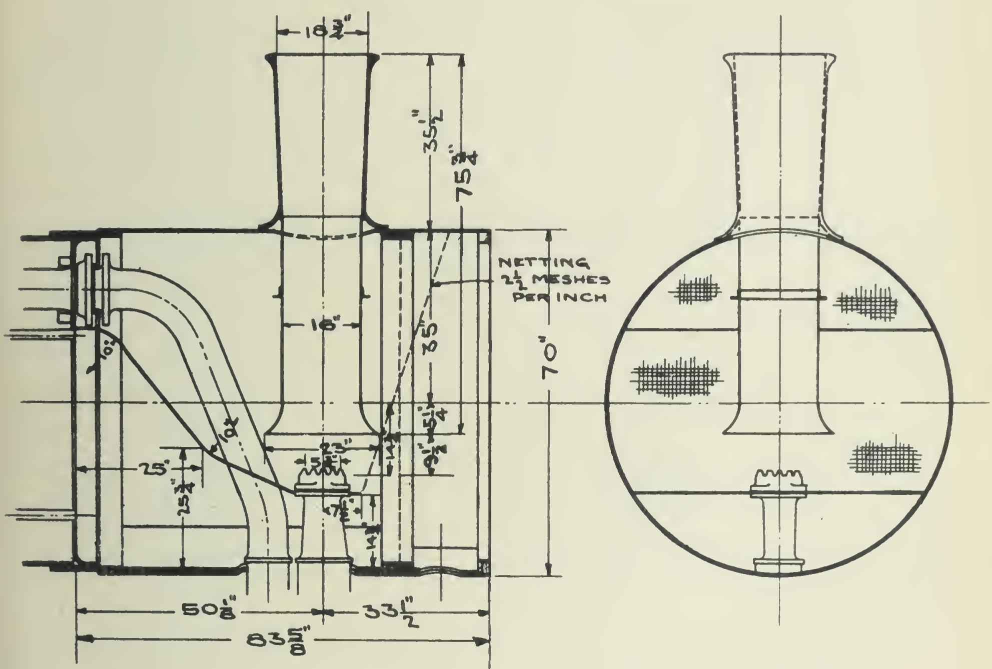


Fig. 18.

The inside stack lowered to clear cinders from plate. This lowering of the stack had the desired effect, but it was too low for good draft.

make it of such a shape that it would clear itself of the small quantity of cinders which had been collecting on it.

74. The plate was made sloping where in the earlier form it had been flat, just back of the exhaust nozzle. The sloping form is shown in Fig. 17. This modification of the form of the sheet

did not have the desired effect, for, in tests Nos. 1003 and 1004 with it, there was as large a quantity of cinders on the plate as before the change.

75. The inside stack was then lengthened as shown in Fig. 18

TEST No. 1007-1008

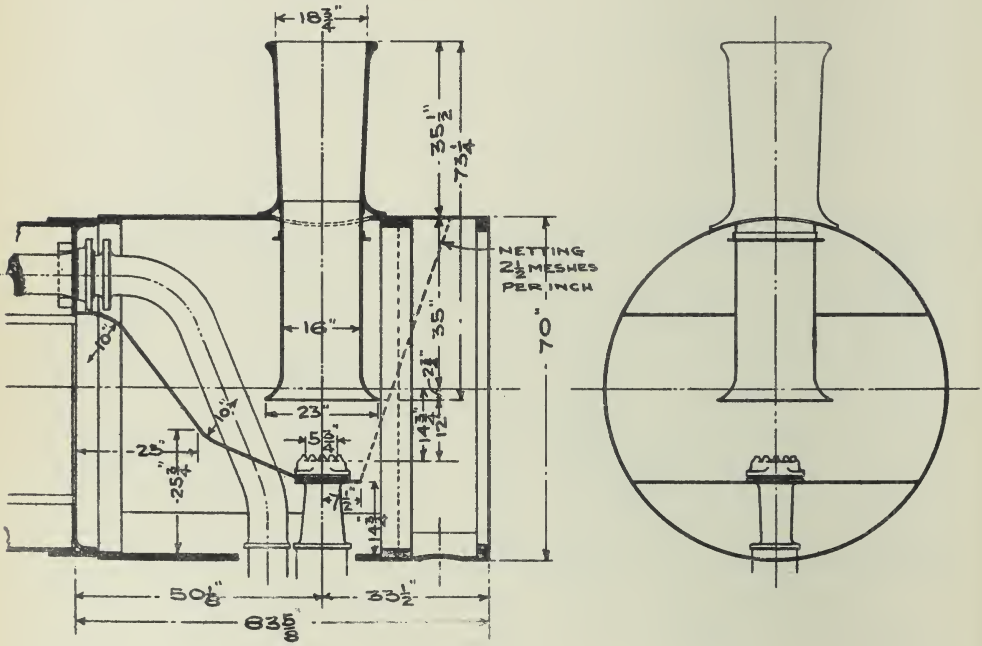


Fig. 19.

This arrangement is the final development of the front end for self-cleaning. The stack is the original standard for the E engines, except that the inside stack is longer. The diaphragm plate is without holes and extends 7½ inches ahead of the center of the nozzle. The fire area of the tubes is 5.26 sq. ft., and the opening for gases under the diaphragm is 3.96 sq. ft. or 75% of the fire area.

where the end of the stack is 9½ inches above the tip of the nozzle. This adjustment had the desired effect, and in tests Nos. 1005 and 1006 the cinders were practically all cleared from the plate.

76. The inside stack was then raised as in Fig. 19, to a point 12 inches above the nozzle, to find the highest position for

this inside stack that would clear the plate of cinders. Six shovelfulls of dry cinders were put on the plate and the locomotive run at a speed of about 120 revolutions and a short cut-off for about 15 minutes, when the cinders were all removed; next, six shovelfulls of wet cinders were put in and these were also cleared from the plate.

77. A test, No. 1007, was then made, using a slack coal of very small size, to note the effect of the self-cleaning feature. At the end of this test, there were a few pounds of cinders on the plate and very little in the bottom of the smokebox.

78. A test was then made, No. 1006, to observe if the capacity of the boiler had been reduced by the changes that had been made. This test gave an equivalent evaporation of 17.63 pounds per hour or practically the same as in test No. 1001, with the arrangement last tried on locomotive 5266.

79. Locomotive 2984 was then removed from the Plant and went into road service equipped with the device, Fig. 19, the final form, which satisfied the conditions of good steaming and self-cleaning.

Table 2.

Self-Cleaning Front Compared With Standard.

Test No.	Test Designation			Duration of Test Hours	Front End Arrangement	Boiler Pressure, Pounds per Square Inch	Evaporation, Dry Steam, per Square Foot of Heating Surface.	Pounds per Hour Equivalent Evaporation per Sq. Ft. of Heating Surface.	Equivalent Evaporation per Pound of Dry Coal	Coal per D. H. P. Hour, Pounds	Coal Fired	Cinders Collected in Smokebox, Pounds per Hour
	M. P. H.	Cut-off	Throttle									
917	37.65	27	Full	3	Fig. 2	188.4	12.24	15.00	7.25	....	Scalp Level	492
900.35	37.65	27	Full	1	Fig. 8	199.9	12.25	14.76	7.28	4.39	Scalp Level	10
900.36	37.65	27	Full	1	Fig. 8	198.6	12.09	14.54	7.87	4.13	Scalp Level	10
900.3	37.65	32	Full	2	Fig. 2	201.2	15.04	18.24	7.01	....	Penn Gas	326
900.37	37.65	32	Full	1	Fig. 8	204.1	15.08	18.17	7.39	4.66	Penn Gas	6
900.45	37.65	32	Full	2	Fig. 16	199.5	14.80	17.89	8.65	4.00	Penn Gas	0
1001	46.27	25	Full	1	Fig. 16	199.6	14.55	17.73	7.33	4.30	Penn Gas	0
1008	46.27	25	Full	1	Fig. 19	202.7	14.38	17.63	8.15	4.02	Penn Gas	0

80. In Table 2, some of the results of the tests of the final form of the self-cleaning front are shown in comparison with the standard front. The tests are in two groups, those with Scalp Level coal being made at a shorter cut-off and lower evaporation than those with Penn Gas coal.

THE H6b CLASS CONSOLIDATION TYPE LOCOMOTIVE.
The type of locomotive used in the Front End tests.

SELF-CLEANING FRONT END FOR CLASS H6b LOCOMOTIVE.

Conclusions and Recommendations on page 53.

INTRODUCTION.

81. The H6 consolidation locomotive on the Lines West has had for some time a self-cleaning front end which is very much like that developed for the E class, and a number of locomotives were equipped with the device.

82. Several other front end arrangements were in use at different places on the Lines East, and in order to determine the relative merits of these devices, in discharging cinders, a series of trials were made on the Locomotive Testing Plant. The locomotive used, was an H6b class, No. 2860.

83. As the trials were made to determine the relative merits of the several devices, each separate device was not taken up and developed, as may have been possible, so that it would give satisfactory results. The tests are comparative, as nearly as they could be made, and the same kind of coal was used in all of them. As the result of these trials with the freight locomotive, a satisfactory self-cleaning front end was found in the arrangement as shown in Fig. 25.

The Standard Front End.

84. The H6b locomotive when designed, had a front end arrangement, as shown in Fig. 20, and this has been a standard on both the H6a and H6b classes. It is in no sense a self-cleaning front end, although some sparks are discharged. A large amount, however, collect in the smokebox and must be removed at the end of each trip.

85. This standard front end has a deflector plate in front of the tube sheet, the purpose of which, is to restrict the draft through the upper rows of tubes where the velocity of the gases is too great, unless a dampening action is introduced by means of such a flat deflector.

86. Automatic cleaning of the front end is accomplished, as has been explained in the former chapter, by creating a rapid motion of the gases through the smokebox by restricting the area of the passage below the diaphragm plate.

Front End with Baffle Plate.

87. One means of creating this rapid flow of gases has been tried on the Lines East with an arrangement like that shown in Fig. 22, this arrangement has an inclined plate covering the whole area of the smokebox at the front end, and the gases, flowing under the edge of the deflector plate, are somewhat restricted by this baffle plate and sparks are carried out of the stack.

The B. & A. V. or Buffalo Self-Cleaning Front End.

88. The front end arrangement shown in Fig. 23 is one that has been in use on the B. & A. Division. It is not unlike the front end developed for the E class, but it differs in having a high exhaust pipe, with the nozzle set high in the smokebox.

Erie Division or Sunbury Self-Cleaning Front End.

89. A self-cleaning front end, developed and used on the Erie Division, is shown in Fig. 24. This has the high exhaust pipe as in Fig. 23, and in addition it has a more complete diaphragm plate, with an inclined front edge. Instead of the inside stack, as in the other front end, this one has two "petticoat" pipes with an opening between the top one and the stack base.

Self-Cleaning Front End as Designed and Used on The Lines West.

90. This front end, Fig. 25, is much like the design worked out for the E class passenger locomotive but adapted to the H6b class. It has a solid diaphragm plate, extending from the tube sheet, downward and forward across the exhaust nozzle, which is set low in the smokebox. The edge of the plate is 6¾ inches in front of the exhaust nozzle centre. The inside stack, or lift pipe, is extended to a point 15¼ inches above the exhaust nozzle.

91. Each of these arrangements was in turn applied to an H6b class locomotive, and a series of trial runs made. The front ends which gave poor results were not further adjusted, but the

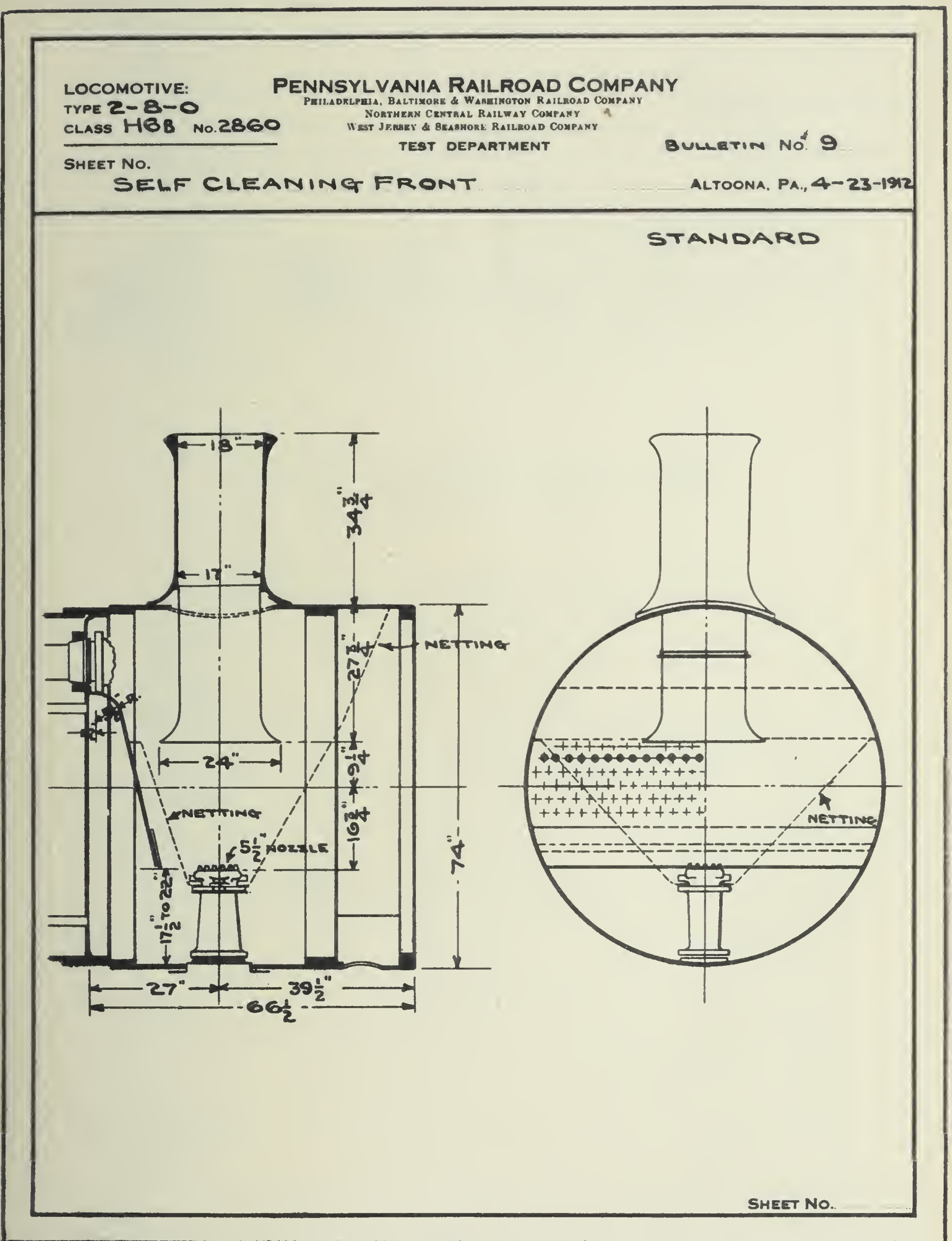


Fig. 20.

The standard front end arrangement for the H6b freight locomotive. There is a perforated deflector in front of the tube sheet. This deflector has an adjustable edge. A netting covers the holes in the deflector plate. This arrangement is not self-cleaning and the cinders must be taken out after each trip.

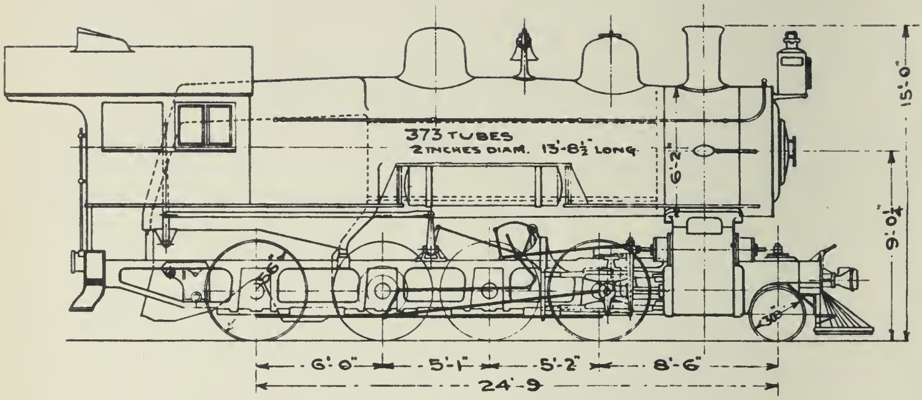


Fig. 21.
GENERAL ARRANGEMENT OF H6b CLASS LOCOMOTIVE.
The Locomotive used in the Tests.

LEADING DIMENSIONS OF LOCOMOTIVE (H6b CLASS)

Total weight, pounds	198,267
Weight on drivers, pounds	176,600
Cylinders (simple), inches	22x28
Diameter of drivers, inches	56
Fire-box heating surface, square feet	166.4
Heating surface in tubes (water side), square feet	2,673.68
Total heating surface (based on water side of tubes), square feet	2,839.74
Total heating surface (based on fire side of tubes), square feet	2,505.29
Grate area, square feet	48.66
Boiler pressure, pounds	205
Valves	Piston
Valve motion	Walschaerts
Fire-box, type	Belpaire
Number of tubes	373
Outside diameter of tubes, inches	2
Length of tubes, inches	164.28

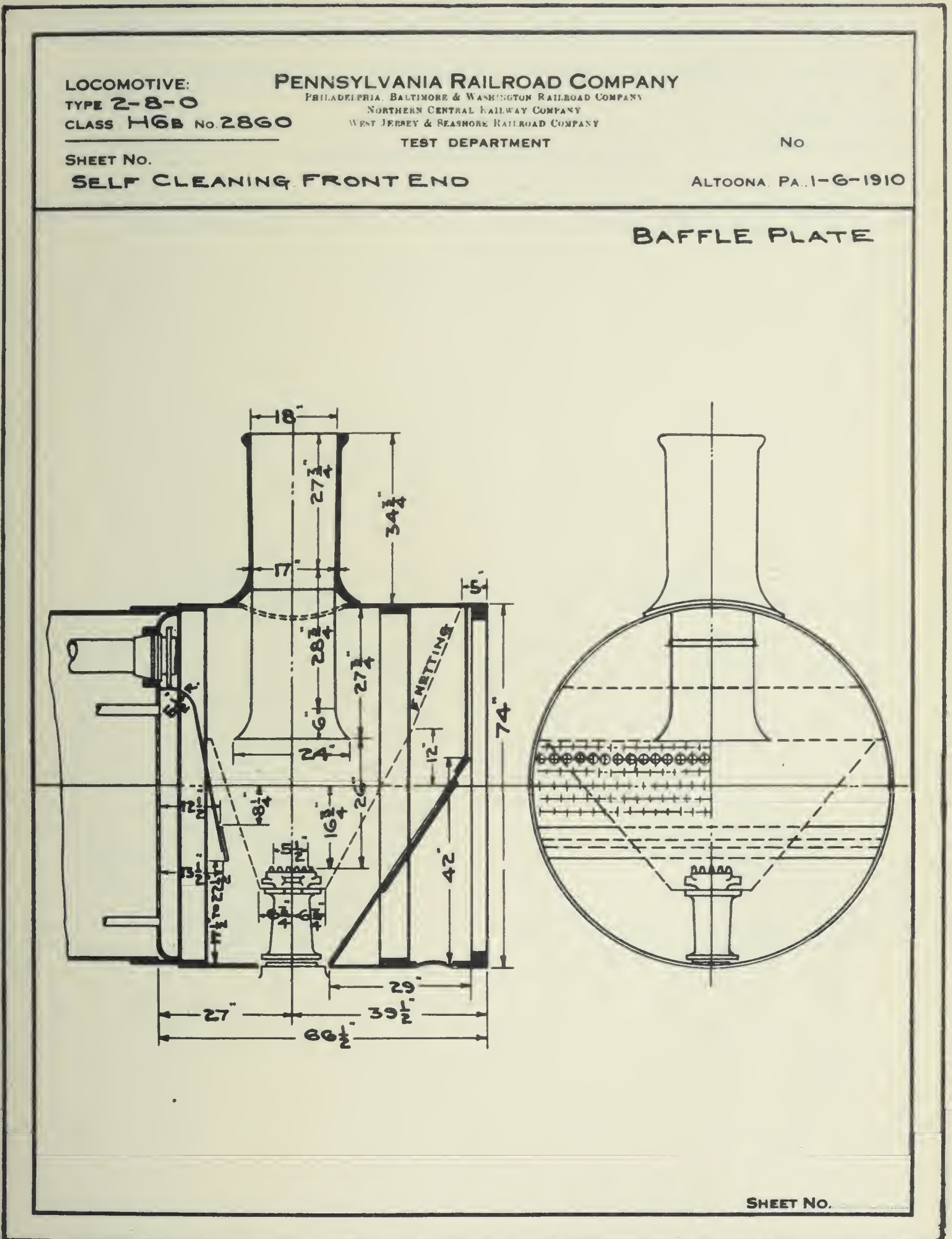


Fig. 22.

Front end with baffle plate. This front end is the same as Fig. 20, but with a plate added covering the whole area of the smokebox in front of the exhaust nozzle. The plate makes the front self-cleaning.

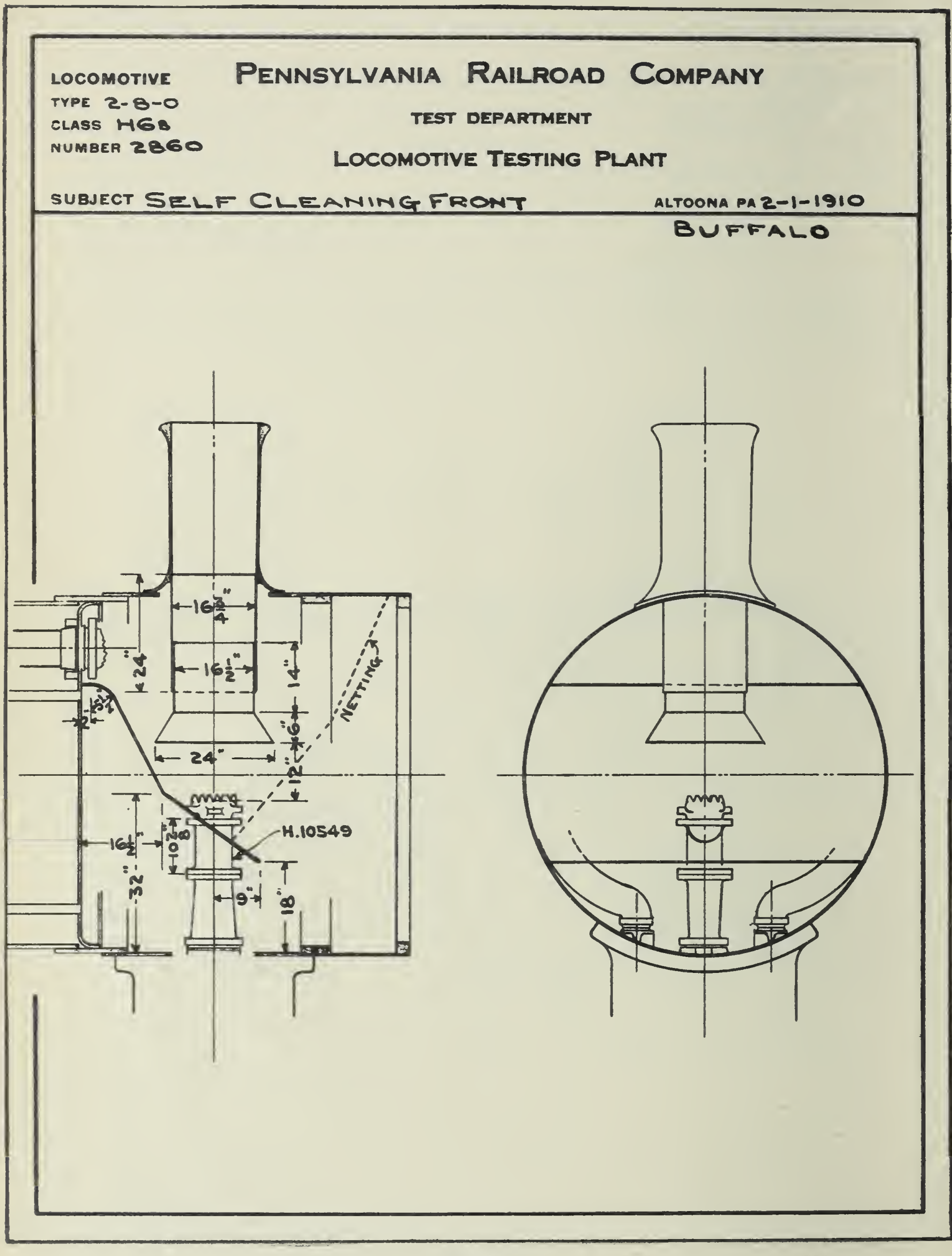


Fig. 23.

A front end arrangement developed and used on the B. & A. V. Division.

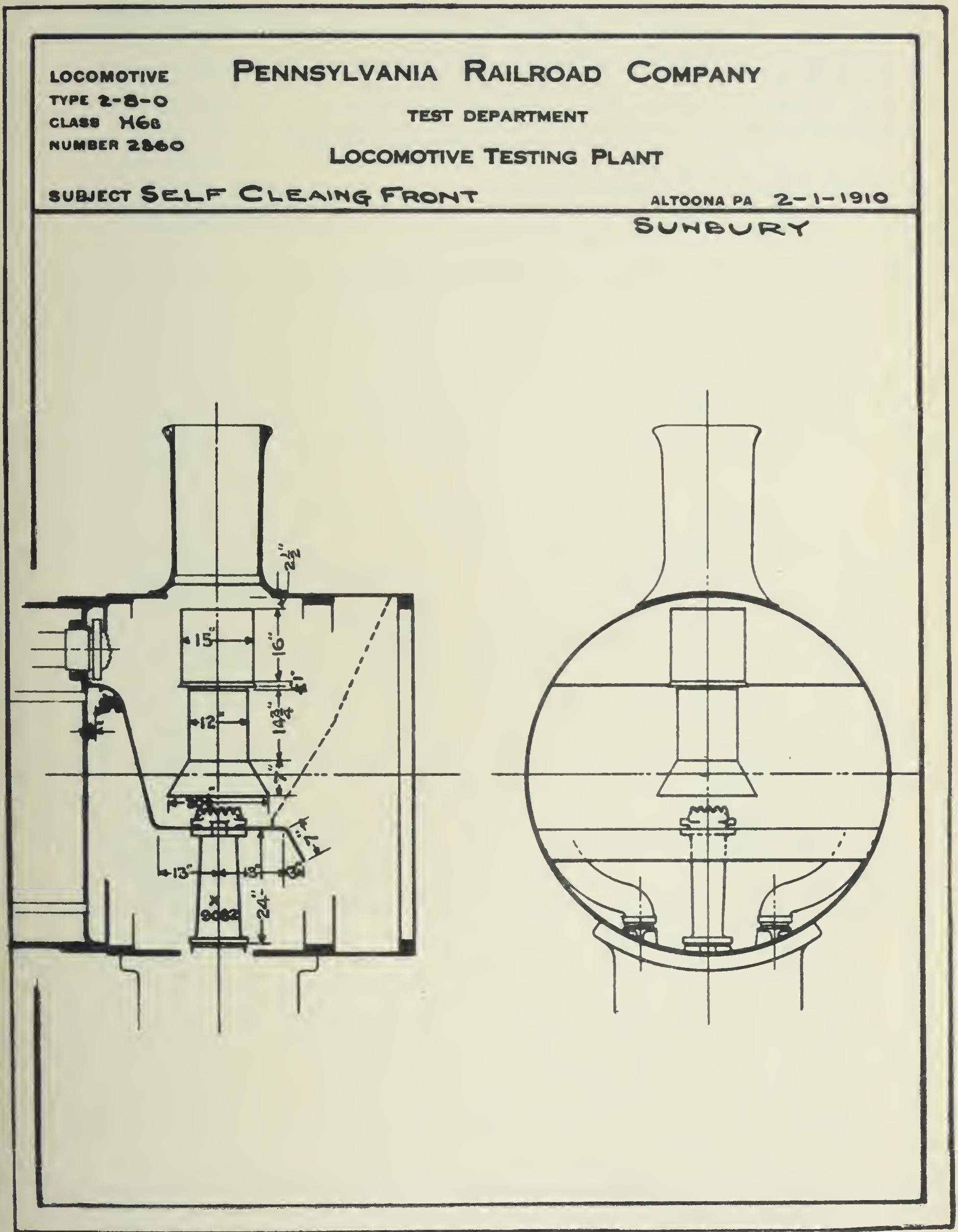


Fig. 24.
A front end arrangement developed and used on the Erie Division.

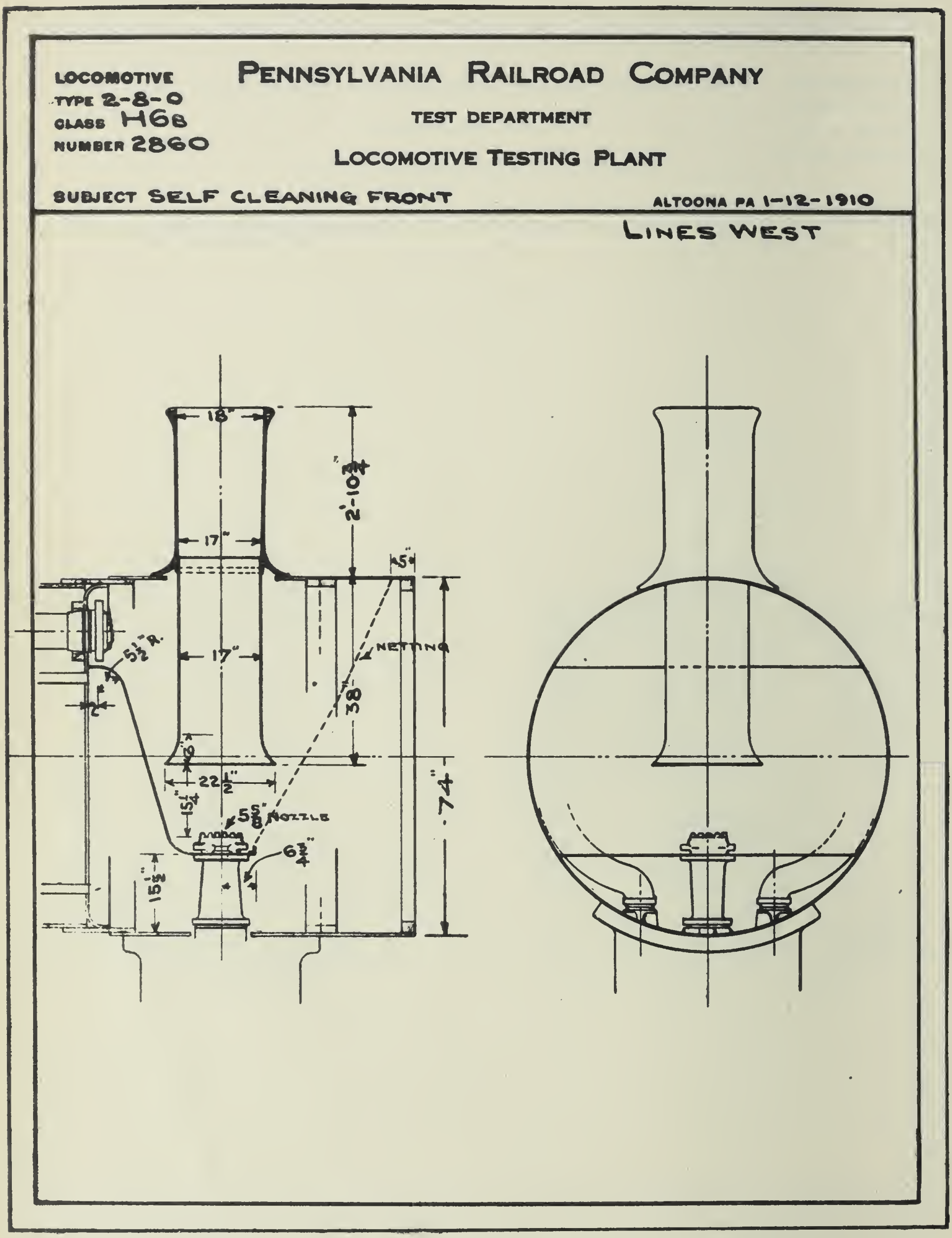


Fig. 25.

A front end arrangement developed and used on the Lines West. This arrangement is simple and easily applied. It gave the best results of any tested.

results were accepted as showing the general performance of the front end being tried. No efficient means of collecting the cinders discharged from the stack was available at the time of the tests, so the only measurement of cinders that could be made was of those remaining in the smokebox.

92. The coal used was Jamison run-of-mine, a high volatile coal which has been used to a considerable extent on the Locomotive Testing Plant with this class of locomotive. It is a bituminous coal of fair quality and contains a considerable amount of small size material, which is discharged as sparks. It is not, however, in this respect, like the low volatile friable coals which form a much larger quantity of sparks.

93. Five or more tests, from one to two hours each, were run with each front end, and the results are shown in Tables 10 to 14. A general summary of the results for a test at about the maximum evaporation for each of the front ends is shown in Table 15.

Table 15.

Front End Arrangement	Test No.	Test Designation			Average Boiler Pressure	Actual Evaporation of Water per Hour	Equivalent Evaporation per Square Foot of Heating Surface.	Draft in Smokebox Inches of Water		Dry Coal, Pounds per D. H. P.	Cinders Collected in Smokebox, Pounds per Hour
		M. P. H.	Cut-off	Throttle				Front of Diaphragm	Back of Diaphragm		
Fig. 25...	1200.446	19.2	45	F	204.9	33722	16.4	6.8	4.9	5.37	17
Fig. 22...	1200.427	19.3	45	F	201.6	32438	15.8	5.7	5.1	4.87	29
Fig. 23...	1200.448	19.2	45	F	188.3	31208	15.2	5.1	4.9	5.56	136
Fig. 24...	1200.440	19.2	45	F	178.9	29820	14.5	5.0	4.0	4.68	11
*Fig. 20...	1200.366	19.4	45	F	192.0	33891	16.2	6.9	6.1	5.13	375

* No test made at this rate with Jamison coal and standard front end. The coal used in this test was similar to Jamison.

94. The test of the arrangement, Fig. 25, shows an average boiler pressure of 204.9 pounds, an evaporation of 33,722 pounds of water, or an equivalent evaporation of 16.4 pounds per square foot of heating surface. The draft in the smokebox was 6.8 inches of water, and the cinders collected were 17 pounds per hour. In the test of arrangement, Fig. 22, it will be noted that the steam pressure, the evaporation and draft in the smokebox are less, while the cinders collected are 29 pounds per hour. The

arrangement, Fig. 23, shows a still lower pressure and evaporation and 136 pounds of cinders collected per hour. The arrangement, Fig. 24, shows a still lower pressure, evaporation and draft, but it shows a very small quantity of cinders collected.

95. It will be noted, however, from Table 14, that this is an exceptionally small quantity of cinders for this front end. Table 9 brings out the fact, that while this front end shows fair results in quantity of cinders, at the same time it shows very poor results in steaming.

96. The results of the tests, showing coal fired and cinders collected in the front end, are illustrated in Fig. 26.

97. The standard front end, as would be expected, shows the largest quantity of cinders collected. The Buffalo arrangement appears to be a little better than the standard front end, which is not self-cleaning. The Sunbury front end is better than the Buffalo front. The baffle plate arrangement comes next in quantity of cinders collected, while the Lines West front, Fig. 25, shows the best results of all, with it, there is formed a small bank of cinders in front of the exhaust pipe, but as this bank does not grow to a large size the front is self-cleaning for all practical purposes.

98. The Lines West front end shows also the best evaporation. While Table 9 gives an evaporation of 33,722 pounds per hour for this front end, the locomotive was actually forced to an evaporation of 34,256 pounds per hour with this arrangement. The average boiler pressure in this latter test was, however, 191.1 pounds, indicating that the limit of boiler capacity was reached or exceeded.

99. The Buffalo and Sunbury front ends would not be difficult or expensive to apply. This does not seem to be the case, however, with the baffle plate arrangement, Fig. 22. It has all of the parts of the original standard front end, with the baffle plate added. This baffle plate has a manhole in it to be used to enter the smokebox for examination. The other front arrangements can be examined by opening the smokebox door, while with this baffle plate the inside manhole plate must be removed.

100. Having eliminated the other front ends for the reasons as given, we have remaining, the Lines West arrangement, Fig. 25. This is a simple and practical front end which gives good results in both steaming and self-cleaning.

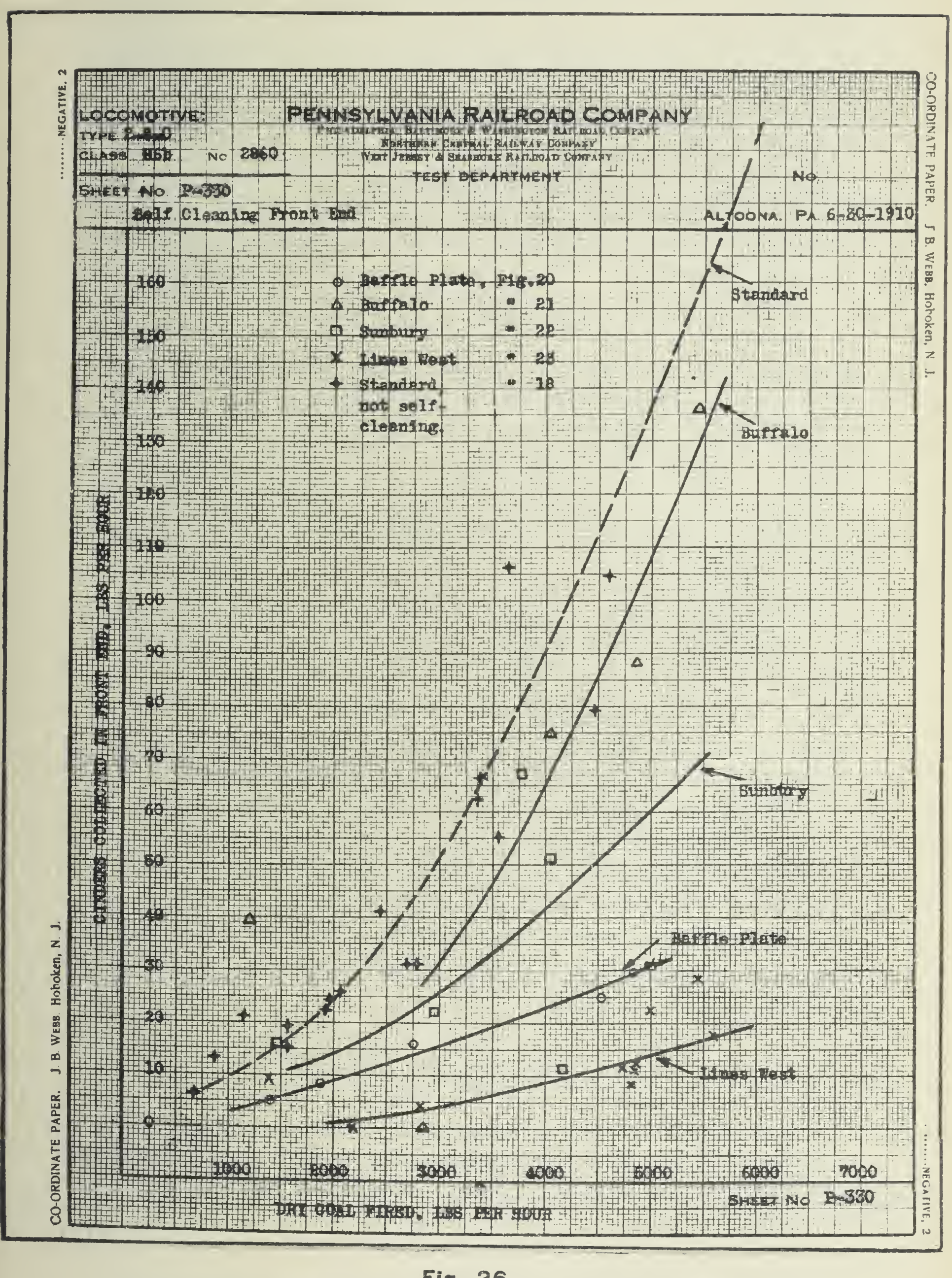


Fig. 26.

Cinders remaining in smokebox and coal fired per hour. This diagram shows how nearly the different arrangements are completely self-cleaning. The Buffalo and Sunbury fronts are little better than the standard, which is not self-cleaning.

Conclusions (E Class).

101. A front end arrangement has been developed for the E class locomotive, which while self-cleaning, maintains the boiler capacity or maximum evaporation fully equal to that with the standard front end arrangement formerly used.

102. With friable coals, where large quanties of cinders are formed, the boiler capacity will be increased on long runs, on account of the smokebox being kept clear of cinders which would obstruct the draft.

103. The outside and inside stacks as now used on this class of locomotive appear to give better results than can be obtained with the form recommended by the Master Mechanics' Committee, and it is thought advisable to retain them.

104. The diaphragm plate may be located at the proper height to produce the cleaning effect desired without causing any difficulty with the burning of the fire. (Paragraphs 29 to 31.)

105. The best results were obtained when the passage for the gases, under the diaphragm, was smooth and free from abrupt changes of form.

106. The inclined, adjustable, diaphragm plate, often used, was found to cause an obstruction to the flow of gases and is undesirable. In the experiments, the height of the whole horizontal plate of the diaphragm was varied and the final position recommended is suitable for any locomotive of this class and means for adjustment is not considered necessary.

107. The front end, Fig. 19, giving the best results is arranged as follows: The diaphragm plate has no holes in it, it extends forward $7\frac{1}{2}$ inches beyond the centre of the exhaust pipe, and the forward edge is $14\frac{3}{4}$ inches above the bottom of the smokebox at the centre. The lower end of the stack is 12 inches above the exhaust nozzle. A $5\frac{3}{4}$-inch exhaust nozzle is used.

Recommendations (E Class).

108. The front end arrangement shown in Fig. 19 is the final development, and is recommended as the one giving the best results.

109. The front end arrangement is of sufficient importance in the steaming of the locomotive to have a periodic inspection for correct location of parts, and we recommend that such an inspection be made at the time of the hydrostatic test of the boiler. A blank form should be provided to be filled in with the diameter of the exhaust nozzle and the actual dimensions of the essential parts of the arrangement.

110. New locomotives, of this class, or locomotives undergoing extensive repairs should have applied the front end as shown in Fig. 19.

Conclusions (H6b Class).

111. Two of these front ends, the Buffalo and Sunbury, are scarcely to be considered as self-cleaning, and the Sunbury front with its petticoat pipe is a very poor steaming arrangement. (Paragraphs 95 and 97.)

112. The baffle plate front end gives fair results in discharging cinders and in steaming, but its extreme complication is very evident.

113. The Lines West front gave very satisfactory results in steaming and cleaning. It is a simple and practical arrangement.

Recommendations (H6b Class).

114. We recommend that in new work or in extensive repair work on smokeboxes of the H6a and H6b classes that the arrangement shown in Fig. 25 be applied, for the reason that it makes a better steaming locomotive at all times, and prevents failures, caused by the filling with cinders and burning out of the smokebox.

C. D. YOUNG,
Engineer of Tests.

Approved:
J. T. WALLIS,
Genl. Supt. Motive Power.

Test Department,
Altoona, Penna.,
August 31, 1912.

M. P. 894A
8 x 10½

7 6 1907

PENNSYLVANIA RAILROAD COMPANY

Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company

TEST DEPARTMENT

AVERAGE RESULTS OF LOCOMOTIVE TESTS

LOCOMOTIVE:
TYPE 4-4-2
CLASS E2a
NUMBER 5266

Bulletin No. 9
TEST NOS., 900.25 to 900.47

SUBJECT: Self-cleaning Front End

ALTOONA, PA., 9-9-07

	DRIVING WHEELS	
1	Number of Pairs	2
2	Approx. Diameter, inches	80
	ENGINE TRUCK WHEELS	
14	Number	4
15	Diameter, inches	36
	TRAILING WHEELS	
16	Diameter, inches	50
	WHEEL BASE, FEET	
17	Driving Wheel Base	7.42
18	Total Wheel Base	30.85
19	Gage of Wheels	56.13
	WEIGHT OF ENGINE WITH WATER AT 2D. GAGE COCK AND NORMAL FIRE, POUNDS	
20	On Truck	37167
21	" 1st Drivers	53334
22	" 2d "	56667
23	" 3d "	——
24	" 4th "	——
25	" 5th "	——
26	" Trailers	37000
27	Total	184167
28	" on Drivers	110000
	CYLINDERS	
	Diam. and Stroke, H. P	20.5 x 26
	" " " L. P	——
	CLEARANCE IN PER CENT. OF PISTON DISPLACEMENT	
40	H. P. Right, Head End	12.7
41	" " Crank "	12.1
42	" Left, Head "	12.4
43	" " Crank "	11.9
44	L. P. Right, Head "	——
45	" " Crank "	——
46	" Left, Head "	——
47	" " Crank "	——
	RECEIVER, CUBIC FEET	
48	Volume Right Side	——
49	" Left "	——
	STEAM PORTS, INCHES	
50	H. P. Admission, Length	19.87
51	" " Width	1.48
58	L. P. " Length	——
59	" " Width	——
66	H. P. Exhaust, Length	19.84
67	" " Width	2.98
70	L. P. " Length	——
71	" " Width	——

	PISTON RODS, DIAMETER INCHES	
74	High Pressure	3.515
75	Low "	——
	TAIL RODS, DIAMETER, INCHES	
78	High Pressure	——
80	Low "	——
	VALVES	
82	Type	Double Ported Bal. Slide
83	Design	American Bal. Valve Co.
84	Per Cent. Balanced	75.7
85	Type of Valve Motion	Stephenson
	GREATEST VALVE TRAVEL	
86	High Pressure, inches	7.0
88	Low " "	——
	OUTSIDE LAP OF VALVE	
90	High Pressure, inches	1.5
94	Low " "	——
	INSIDE LAP OF VALVE	
98	High Pressure, inches	Neg. .16
102	Low " "	——
	BOILER	
113	Type	Belpaire Wide Fire box
114	Outside Diam. 1st Ring	67.0
	TUBES	
115	Number	315
116	Outside Diam., inches	2
	Pitch "	2.625
118	Length Between Tube Sheets, inches	179.78
119	Total Fire Area, sq. ft.	5.26
124	Boiler Pressure, pounds	205
	SUPERHEATER	
125	Number of Tubes	——
126	Outside Diam. " inches	——
128	Length of " "	——
	FIREBOX, INSIDE, INCHES	
132	Length	114.0
133	Width	68.0
137	Air Inlets to Ashpan, sq. ft.	6.3
	GRATES	
144	Type	Rocking Finger
145	Grate Area, sq. ft.	55.5
146	Area of Dead Grates	6.0

	HEATING SURFACE, SQUARE FEET	
154	Of the Tubes, Water Side	2471.04
155	" " " Fire "	2162.40
156	" " Firebox, " "	156.86
157	" " Superh'r, " "	——
*158	Total, Based on " "	2319.26
159	" " " " " of Firebox and Water Side of Tubes	2627.90
	BOILER VOLUME WITH WATER SURFACE AT LEVEL OF 2D GAGE COCK	
160	Water Space, cu. ft.	338.6
161	Steam " " "	109.9
	EXHAUST NOZZLE	
162	Double or Single	Single
163	Size, inches	5.625
167	Area, sq. inches	24.85
	REVERSE LEVER	
168	H. P. Notches Forward of Center	15
169	L. P. Notches Forward of Center	——
	RATIOS	
171	Heating Surface (158) to Grate Area (145)	41.79
172	Fire Area Thru Tubes (119) to Grate Area (145)	.09
173	Firebox Heating Surface (156) to Grate Area (145)	2.83
174	Tube Heating Surface (155) to Fire Box Heating Surface (156)	13.79

*USED IN CALCULATIONS

Table 3.
Dimensions of E2a locomotive 5266.

M. P. 394 A—Sixth Sheet
8 x 10½

11-9-10

PENNSYLVANIA RAILROAD COMPANY

Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company

TEST DEPARTMENT

AVERAGE RESULTS OF LOCOMOTIVE TESTS

LOCOMOTIVE:
TYPE 4-4-2
CLASS E2a
NUMBER 5266

FUEL: Scalp Level and Penn Gas Coal

SUBJECT: Front End Trials

ALTOONA, PA., 9-9-1907

TEST NUMBER	RUNNING CONDITIONS: TEST DESIGNATION	Duration of Test, Hours	Miles per Hour	Throttle Opening, Full or Partial	Actual Cut-off Per Cent., H. P. Cylinders	Draft in Firebox	BOILER PERFORMANCE: Pressure in Boiler, Lbs. per Sq. Inch	Draft in Smoke Box, Inches of Water	Draft in Ash Pan, Inches of Water	Calorific Value of Dry Fuel, B. T. U. per Lb.	Cinders Collected in Smoke Box, Pounds per Hour
	R. P. M. Cut-off Throttle	196	199	203	268 to 271		217	222	225	248	238
917	160-27-F	3.0	38.20	Full		2.1	188.4	7.7	0.3	15167	492
900.3	160-32-F	2.0	37.65	"		2.5	201.2	8.3	0.2	14360	326
900.25	160-27-F	1.5	37.65	"		1.2	179.2	4.9	0.2	15402	0
900.26	160-27-F	1.0	37.65	"		1.1	181.4	4.8	0.2	15402	0
900.28	160-25-F	2.0	37.65	"		1.2	199.0	5.0	0.2	15402	0
900.29	160-30-F	1.0	37.65	"		1.5	173.3	5.6	0.2	15402	0
900.30	160-27-F	1.0	37.65	"		1.5	186.9	5.3	0.2	15402	0
900.31	160-27-F	1.5	37.65	"		1.3	176.7	4.8	0.2	15402	0
900.32	160-27-F	1.0	37.65	"		1.4	195.1	5.2	0.2	15402	48
900.33	160-32-F	1.0	37.65	"		2.6	179.0	6.8	0.2	14229	28

TEST NUMBER	BOILER PERFORMANCE: Dry Fuel Fired per Hour, Pounds	Dry Fuel per Hour, Pounds per Sq. Ft. of Grate	Water Delivered to Boiler, Pounds per Hour	Equivalent Evaporation from and at 212° F., Pounds: Per Hour	Per Hour per Sq. Ft. of Fire Heating Sur.	Per Pound of Dry Fuel	Boiler Horse Power (34½ U. of E.)	Efficiency of Boiler, Based on Fuel	Draft Back of Diaph.	ENGINE PERFORMANCE: Pressure in Branch Pipe, Pounds per Sq. In.	Superheat in Branch Pipe, Degrees F.
	338	339	340	344	345	347	349	350		220	230
917	4802	86.53	28670	34793	15.00	7.25	1008.5	46.17	6.2		
900.3	6039	108.81	35232	42305	18.24	7.01	1226.3	47.15	4.2		
900.25	3749	67.55	25115	29866	12.88	7.97	865.7	49.98	3.2		
900.26	4115	74.14	26296	31288	13.49	7.60	906.9	47.66	3.3		
900.28	4169	75.13	26182	31236	13.47	7.49	905.4	46.97	3.3		
900.29	4392	79.14	28243	33577	14.48	7.65	973.3	47.97	4.0		
900.30	4462	80.40	27270	32532	14.03	7.29	943.0	45.71	3.7		
900.31	3903	70.32	25797	30707	13.24	7.87	890.1	49.35	3.4		
900.32	4446	80.11	27990	33362	14.38	7.50	967.0	47.03	4.3		
900.33	5825	104.95	31613	37627	16.22	6.46	1090.7	43.85	5.9		

TEST NUMBER	ENGINE PERFORMANCE: Dry Steam to Engines, Pounds per Hour	Indicated Horse Power	Dry Fuel per Indicated Horse Power Hour, Pounds	Dry Steam per Indicated Horse Power Hour, Pounds	Front End	LOCOMOTIVE PERFORMANCE: Drawbar Pull, Pounds	Dynamometer or Drawbar Horse Power	Dry Fuel per Dynamom. Horse Power Hour, Pounds	Dry Steam per Dynamom. Horse Power Hour, Pounds	Machine Efficiency of Locomotive, Per Cent.	Thermal Efficiency of Locomotive, per Cent., (Based on Fuel)	Exhaust Nozzle Diameter
	214	379	380	381		265	383	384	385	398	399	
917					Fig.2	8757	892.1	5.38	31.34		3.10	5.625
900.3					" 2	10535	1193.6	5.06	29.2		3.5	5.625
900.25					" 8	8684	872.0	4.30	28.51		3.84	5.625
900.26					" 9	8785	882.2	4.66	29.50		3.55	5.625
900.28					" 9	8926	896.3	4.65	28.89		3.55	5.750
900.29					" 10	9970	1001.2	4.39	27.92		3.76	5.750
900.30					" 10	9529	956.9	4.66	28.21		3.55	5.750
900.31					" 10	8927	896.4	4.35	28.49		3.80	5.825
900.32					" 10	10190	1023.3	4.34	27.06		3.81	5.750
900.33					" 10	10803	1084.8	5.37	28.84		3.33	5.750

Table 4.
Results of front end tests, E2a class locomotive.

M. P. 394 A—Sixth Sheet
8 x 10½

11-9-10

PENNSYLVANIA RAILROAD COMPANY

Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company

TEST DEPARTMENT

AVERAGE RESULTS OF LOCOMOTIVE TESTS

LOCOMOTIVE:
TYPE 4-4-2
CLASS E2a
NUMBER 5266

FUEL: Penn Gas and Scalp Level Coal

SUBJECT: Front End Trials

ALTOONA, PA., 9-9-1907

TEST NUMBER	RUNNING CONDITIONS: Test Designation						BOILER PERFORMANCE: Pressure in Boiler, Lbs. per Sq. Inch				
	Test Designation	Duration of Test, Hours	Miles per Hour	Throttle Opening, Full or Partial	Actual Cut-off Per Cent., H. P. Cylinders	Draft in Firebox	Pressure in Boiler, Lbs. per Sq. Inch	Draft in Smoke Box, Inches of Water	Draft in Ash Pan, Inches of Water	Calorific Value of Dry Fuel, B. T. U. per Lb.	Cinders Collected in Smoke Box, Pounds per Hour
	R. P. M. Cut-off Throttle	196	199	203	268 to 271		217	222	225	248	238
900.35	160-27-F	1.0	37.65	Full		1.4	199.9	5.5	0.3	15402	10
900.36	160-27-F	1.0	37.65	"		1.4	198.6	6.3	0.3	15402	10
900.37	160-32-F	1.0	37.65	"		2.9	204.1	9.5	0.3	14233	6
900.38	160-27-F	1.0	37.65	"		1.5	200.4	5.9	0.3	15402	255
900.39	160-27-F	1.0	37.65	"		1.4	184.3	6.0	0.3	15402	76
900.40	160-27-F	0.5	37.56	"		1.2	172.5	4.5	0.2	15402	0

TEST NUMBER	BOILER PERFORMANCE			EQUIVALENT EVAPORATION FROM AND AT 212° F., POUNDS						ENGINE PERFORMANCE	
	Dry Fuel Fired per Hour, Pounds	Dry Fuel per Hour, Pounds per Sq. Ft. of Grate	Water Delivered to Boiler, Pounds per Hour	Per Hour	Per Hour per Sq. Ft. of Fire Heating Sur.	Per Pound of Dry Fuel	Boiler Horse Power (34½ U. of E.)	Efficiency of Boiler, Based on Fuel	Draft Back of Diaph.	Pressure in Branch Pipe, Pounds per Sq. In.	Superheat in Branch Pipe Degrees F.
	338	339	340	344	345	347	349	350		220	230
900.35	4702	84.72	28693	34243	14.76	7.28	992.6	45.65	4.5		
900.36	4285	77.21	28318	33717	14.54	7.87	977.3	49.35	4.6		
900.37	5702	102.74	35326	42141	18.17	7.39	1221.5	50.15	7.4		
900.38	4206	75.78	29201	34840	15.02	8.28	1009.9	31.92	4.7		
900.39	4478	80.68	26430	31502	13.58	7.03	913.1	44.08	3.9		
900.40									3.1		

TEST NUMBER	ENGINE PERFORMANCE					LOCOMOTIVE PERFORMANCE						
	Dry Steam to Engines, Pounds per Hour	Indicated Horse Power	Dry Fuel per Indicated Horse Power Hour, Pounds	Dry Steam per Indicated Horse Power Hour, Pounds	Front End	Drawbar Pull, Pounds	Dynamometer or Drawbar Horse Power	Dry Fuel per Dynamom. Horse Power Hour, Pounds	Dry Steam per Dynamom. Horse Power Hour, Pounds	Machine Efficiency of Locomotive, Per Cent.	Thermal Efficiency of Locomotive, per Cent., (Based on Fuel)	Exhaust Nozzle Diameter
	214	379	380	381		285	383	384	385	398	399	
900.35					Fig. 8	10418	1046.2	4.49	27.12		3.68	5.75
900.36					" 8	10324	1036.7	4.13	27.04		4.00	5.75
900.37					" 8	12198	1224.9	4.66	28.45		3.84	5.75
900.38					" 11		No record					5.75
900.39					" 11		"					5.75
900.40					" 12	8596						6.25

Table 5.
Results of front end tests, E2a class locomotive.

M. P. 394 A—Sixth Sheet
8 x 10½

11-9-10

PENNSYLVANIA RAILROAD COMPANY

Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company

TEST DEPARTMENT

AVERAGE RESULTS OF LOCOMOTIVE TESTS

LOCOMOTIVE:
TYPE 4-4-2
CLASS E2a
NUMBER 5266

FUEL: Penn Gas Coal

SUBJECT: Front End Trials

ALTOONA, PA. 10-1-1907

TEST NUMBER	RUNNING CONDITIONS: TEST DESIGNATION	Duration of Test, Hours	Miles per Hour	Throttle Opening, Full or Partial	Actual Cut-off Per Cent., H. P. Cylinders	Draft in Firebox	BOILER PERFORMANCE: Pressure in Boiler, Lbs. per Sq. Inch	Draft in Smoke Box, Inches of Water	Draft in Ash Pan, Inches of Water	Calorific Value of Dry Fuel, B. T. U. per Lb.	Cinders Collected in Smoke Box, Pounds per Hour
	R. P. M. Cut-off Throttle	196	199	203	268 to 271		217	222	225	248	238
900.41	160-27-F	2	37.56	Full		2.1	200.8	6.9	0.3	14382	0
900.42	160-27-F	2	37.56	"		1.9	203.4	6.7	0.3	"	0
900.43	160-27-F	2	37.56	"		2.0	204.6	7.1	0.3	"	0
900.44	160-27-F	2	37.56	"		1.9	202.3	6.8	0.3	"	0
900.45	160-32-F	2	37.56	"		2.5	199.5	8.7	0.4	"	0
900.46	160-27-F	2	37.56	Partial		0.6	205.8	1.8	0.2	"	3
900.47	160-27-F	2	37.56	Full		1.9	195.8	5.7	0.3	"	10

TEST NUMBER	BOILER PERFORMANCE: Dry Fuel Fired per Hour, Pounds	Dry Fuel per Hour, Pounds per Sq. Ft. of Grate	Water Delivered to Boiler, Pounds per Hour	Equivalent Evaporation from and at 212° F., Pounds: Per Hour	Per Hour per Sq. Ft. of Fire Heating Sur.	Per Pound of Dry Fuel	Boiler Horse Power (34½ U. of E.)	Efficiency of Boiler, Based on Fuel	Draft Back of Diaph.	ENGINE PERFORMANCE: Pressure in Branch Pipe, Pounds per Sq. In.	Superheat in Branch Pipe, Degrees F.
	338	339	340	344	345	347	349	350		220	230
900.41	4489	80.88	31165	37282	16.07	8.31	1080.7	55.80	5.5		
900.42	3888	70.05	29706	35552	15.33	9.14	1030.5	61.38	5.2		
900.43	4641	83.62	31032	37177	16.03	8.01	1077.6	53.79	5.6		
900.44	3776	68.04	30437	36458	15.72	9.66	1056.8	64.87	5.4		
900.45	4799	86.47	34676	41497	17.89	8.65	1202.8	58.09	6.7		
900.46	1421	25.60	14206	16970	7.32	11.94	491.9	80.18	1.5		
900.47	4030	72.61	28882	34525	14.89	8.57	1000.7	57.55	4.6		

TEST NUMBER	ENGINE PERFORMANCE: Dry Steam to Engines, Pounds per Hour	Indicated Horse Power	Dry Fuel per Indicated Horse Power Hour, Pounds	Dry Steam per Indicated Horse Power Hour, Pounds	Front End	LOCOMOTIVE PERFORMANCE: Drawbar Pull, Pounds	Dynamometer or Drawbar Horse Power	Dry Fuel per Dynamom. Horse Power Hour, Pounds	Dry Steam per Dynamom. Horse Power Hour, Pounds	Machine Efficiency of Locomotive, Per Cent.	Thermal Efficiency of Locomotive, per Cent., (Based on Fuel)	Exhaust Nozzle Diameter
	214	379	380	381		265	383	384	385	398	389	
900.41					Fig. 14	10822	1084.1	4.14	28.46		4.27	5.75
900.42					" 15	10334	1035.3	3.76	28.39		4.71	5.75
900.43					" 15	10250	1026.8	4.52	29.66		3.91	5.75
900.44					" 16	10400	1041.9	3.62	28.91		4.89	5.75
900.45					" 16	11967	1198.9	4.00	28.63		4.42	5.75
900.46					" 16	3994	400.1	3.55	34.63		4.98	5.75
900.47					" 16	10142	1016.0	3.97	28.13		4.46	5.75

Table 6.
Results of front end tests, E2a class locomotive.

M. P. 894A
8 x 10½

7 6 1907

Pennsylvania Railroad Company

Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company

TEST DEPARTMENT

Average Results of Locomotive Tests

LOCOMOTIVE:
TYPE 4-4-2
CLASS E3a
NUMBER 2984

Bulletin No. 9
TEST NOS., 1001 to 1008 incl.

SUBJECT: Self-cleaning Front End

ALTOONA, PA., 11-4-07

	Driving Wheels	
1	Number of Pairs	2
2	Approx. Diameter, inches	80
	Engine Truck Wheels	
14	Number	4
15	Diameter, inches	36
	Trailing Wheels	
16	Diameter, inches	50
	Wheel Base, Feet	
17	Driving Wheel Base	7.42
18	Total Wheel Base	30.85
19	Gage of Wheels	4.71
	Weight of Engine with Water at 2d. Gage Cock and Normal Fire, Pounds	
20	On Truck	33700
21	" 1st Drivers	56700
22	" 2d "	61500
23	" 3d "	——
24	" 4th "	——
25	" 5th "	——
26	" Trailers	31200
27	Total	183100
28	" on Drivers	118200
	Cylinders	
	Diam. and Stroke, H. P	22 x 26
	" " " L. P.	——
	Clearance in per cent. of piston displacement	
40	H. P. Right, Head End	+
41	" " Crank "	+
42	" Left, Head "	+
43	" " Crank "	+
44	L. P. Right, Head "	——
45	" " Crank "	——
46	" Left, Head "	——
47	" " Crank "	——
	Receiver, Cubic Feet	
48	Volume Right Side	——
49	" Left "	——
	Steam Ports, Inches	
50	H. P. Admission, Length	20
51	" " Width	1.5
58	L. P. " Length	——
59	" " Width	——
66	H. P. Exhaust, Length	20
67	" " Width	3
70	L. P. " Length	——
71	" " Width	——

	Piston Rods, Diameter Inches	
74	High Pressure	4
76	Low "	——
	Tail Rods, Diameter, Inches	
78	High Pressure	——
80	Low "	——
	Valves	
82	Type	Richardson Balanced
83	Design	
84	Per Cent. Balanced	
85	Type of Valve Motion	Stephenson
	Greatest Valve Travel	
86	High Pressure, inches	+
88	Low " "	——
	Outside Lap of Valve	
90	High Pressure, inches	+
94	Low " "	——
	Inside Lap of Valve	
98	High Pressure, inches	+
102	Low " "	——
	Boiler	
113	Type	Belpaire Wide Fire Box
114	Outside Diam. 1st Ring	67
	Tubes	
115	Number	315
116	Outside Diam., inches	2
	Pitch "	2.625
118	Length Between Tube Sheets, inches	179.78
119	Total Fire Area, sq. ft.	5.26
124	Boiler Pressure, pounds	205
	Superheater	
125	Number of Tubes	——
126	Outside Diam. " inches	——
128	Length of " "	——
	Firebox, Inside, Inches	
132	Length	114
133	Width	68
137	Air Inlets to Ashpan, sq. ft.	6.3
	Grates	
144	Type	Rocking Finger
145	Grate Area, sq. ft.	55.5
146	Area of Dead Grates	6.0

	Heating Surface, Square Feet	
154	Of the Tubes, Water Side	2471.04
155	" " " Fire "	2162.40
156	" " Firebox, " "	156.86
157	" " Superh'r, " "	——
*158	Total, Based on " "	2319.26
159	" " " " " of Firebox and Water Side of Tubes	2627.90
	Boiler Volume with water surface at level of 2d gage cock	
160	Water Space, cu. ft.	+
161	Steam " " "	+
	Exhaust Nozzle	
162	Double or Single	Single
163	Size, inches	5.75
167	Area, sq. inches	25.97
	Reverse Lever	
168	H. P. Notches Forward of Center	15
169	L. P. Notches Forward of Center	——
	Ratios	
171	Heating Surface (158) to Grate Area (145)	41.79
172	Fire Area Thru Tubes (119) to Grate Area (145)	.09
173	Firebox Heating Surface (156) to Grate Area (145)	2.83
174	Tube Heating Surface (155) to Fire Box Heating Surface (156)	13.79

+ These items not measured

*USED IN CALCULATIONS

Table 7.
Dimensions of E3a class locomotive 2984.

M. P. 394 A—Sixth Sheet
8 x 10½

11-9-10

PENNSYLVANIA RAILROAD COMPANY

Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company

TEST DEPARTMENT

AVERAGE RESULTS OF LOCOMOTIVE TESTS

LOCOMOTIVE:
TYPE 4-4-2
CLASS E3a
NUMBER 2984

FUEL: Penn Gas Coal

SUBJECT: Front End Tests

ALTOONA, PA., 11-4-1907

TEST NUMBER	RUNNING CONDITIONS						BOILER PERFORMANCE				
	TEST DESIGNATION	Duration of Test, Hours	Miles per Hour	Throttle Opening, Full or Partial	Actual Cut-off Per Cent., H. P. Cylinders	Draft in Firebox	Pressure in Boiler, Lbs. per Sq. inch	Draft in Smoke Box, Inches of Water	Draft in Ash Pan, Inches of Water	Calorific Value of Dry Fuel, B. T. U. per Lb.	Cinders Collected in Smoke Box, Pounds per Hour
	R. P. M. Cut-off Throttle	196	199	203	268 to 271		217	222	225	248	238
1001	200-25-F	1.00	46.27	Full		2.3	199.6	8.6	0.3	14088	0
1002	160-30-F	1.00	37.02	"		2.2	201.9	8.7	0.3	14088	0
1003	160-30-F	0.33	37.02	"		1.8	200.5	7.2	0.3	14088	0
1004	160-25-F	2.00	37.02	"		1.9	199.9	6.7	0.4	14088	0
1005	120-20-F	2.00	27.76	"		1.2	202.7	3.6	0.2	14088	0
1006	160-30-F	1.00	37.02	"		2.2	200.4	7.2	0.4	14088	0
1007	160-23-F	1.00	37.02	"		1.8	200.4	5.6	0.3	11917	0
1008	200-25-F	1.00	46.27	"		2.2	202.7	7.1	0.4	14616	0

TEST NUMBER	BOILER PERFORMANCE									ENGINE PERFORMANCE	
	Dry Fuel Fired per Hour, Pounds	Dry Fuel per Hour, Pounds per Sq. Ft. of Grate	Water Delivered to Boiler, Pounds per Hour	Equivalent Evaporation from and at 212° F., Pounds: Per Hour	Equivalent Evaporation: Per Hour per Sq. Ft. of Fire Heating Sur.	Equivalent Evaporation: Per Pound of Dry Fuel	Boiler Horse Power (34½ U. of E.)	Efficiency of Boiler, Based on Fuel	Draft Back of Diaph.	Pressure in Branch Pipe, Pounds per Sq. in.	Superheat in Branch Pipe Degrees F.
	338	339	340	344	345	347	349	350		220	230
1001	5523	99.51	34088	41111	17.73	7.44	1191.7	51.00	6.1		
1002	4321	77.86	33330	40142	17.31	9.29	1163.6	63.69	5.9		
1003	4577	82.47	32211	38370	16.76	8.49	1126.7	58.20	5.3		
1004	3803	68.52	30000	36255	15.63	9.56	1050.9	65.33	4.9		
1005	2503	45.10	20823	25183	10.86	10.06	730.0	68.97	2.7		
1006	4501	81.10	32375	39237	16.92	8.72	1137.3	59.78	5.2		
1007	4409	79.44	25970	31297	13.49	7.10	907.2	57.54	4.3		
1008	5016	90.38	33695	40891	17.63	8.15	1185.3	53.85	5.6		

TEST NUMBER	ENGINE PERFORMANCE					LOCOMOTIVE PERFORMANCE						
	Dry Steam to Engines, Pounds per Hour	Indicated Horse Power	Dry Fuel per Indicated Horse Power Hour, Pounds	Dry Steam per Indicated Horse Power Hour, Pounds	Front End	Drawbar Pull, Pounds	Dynamometer or Drawbar Horse Power	Dry Fuel per Dynamom. Horse Power Hour, Pounds	Dry Steam per Dynamom. Horse Power Hour, Pounds	Machine Efficiency of Locomotive, Per Cent	Thermal Efficiency of Locomotive, per Cent., (Based on Fuel)	Exhaust Nozzle Diameter
	214	379	380	381		265	383	384	385	398	399	
1001					Fig. 16	10397	1283.0	4.30	26.26		4.20	5.75
1002					" 16	12914	1274.9	3.39	25.87		5.33	5.75
1003					" 17	12717	1255.4	3.65	25.40		4.95	5.75
1004					" 17	11876	1172.4	3.24	25.32		5.58	5.75
1005					" 18	10957	811.3	3.09	25.40		5.85	5.75
1006					" 18	12765	1260.2	3.57	25.34		5.06	5.75
1007					" 19	10605	1046.6	4.21	24.49		5.07	5.75
1008					" 19	10109	1247.5	4.02	26.66		4.33	5.75

Table 8.

Results of front end tests, E3a class locomotive.

M. P. 894A
8 x 10½

7 6 1907

PENNSYLVANIA RAILROAD COMPANY

Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company

TEST DEPARTMENT

AVERAGE RESULTS OF LOCOMOTIVE TESTS

Bulletin No.9

TEST NOS.,

LOCOMOTIVE:
TYPE 2-8-0
CLASS H8b
NUMBER 2860

SUBJECT: Self Cleaning Front End

ALTOONA, PA. 8-10-1908

	DRIVING WHEELS	
1	Number of Pairs	4
2	Approx. Diameter, inches	56
	ENGINE TRUCK WHEELS	
14	Number	2
15	Diameter, inches	30
	TRAILING WHEELS	
16	Diameter, inches	—
	WHEEL BASE, FEET	
17	Driving Wheel Base	16.25
18	Total Wheel Base	24.84
19	Gage of Wheels	4.75
	WEIGHT OF ENGINE WITH WATER AT 2D GAGE COCK AND NORMAL FIRE POUNDS	
20	On Truck	21667
21	" 1st Drivers	45667
22	" 2d "	42583
23	" 3d "	47500
24	" 4th "	40850
25	" 5th "	—
26	" Trailers	—
27	Total	198267
28	" on Drivers	176600
	CYLINDERS	
	Diam. and Stroke, H. P	22 x28
	" " " L. P	—
	CLEARANCE IN PER CENT. OF PISTON DISPLACEMENT	
40	H. P. Right, Head End	12.5
41	" " Crank "	10.7
42	" Left, Head "	12.2
43	" " Crank "	10.8
44	L. P. Right, Head "	—
45	" " Crank "	—
46	" Left, Head "	—
47	" " Crank "	—
	RECEIVER, CUBIC FEET	
48	Volume Right Side	—
49	" Left "	—
	STEAM PORTS, INCHES	
50	H. P. Admission, Length	30
51	" " Width	2
58	L. P. " Length	—
59	" " Width	—
66	H. P. Exhaust, Length	No Port
67	" " Width	" "
70	L. P. " Length	—
71	" " Width	—

	PISTON RODS, DIAMETER INCHES	
74	High Pressure	4
76	Low "	—
	TAIL RODS, DIAMETER, INCHES	
78	High Pressure	None
80	Low "	—
	VALVES	
82	Type	Piston
83	Design	Amer.Bal.Valve Co.
84	Per Cent. Balanced	100
85	Type of Valve Motion	Walschaerts
	GREATEST VALVE TRAVEL	
86	High Pressure, inches	6.25
88	Low " "	—
	OUTSIDE LAP OF VALVE	
90	High Pressure, inches	.91
94	Low " "	—
	INSIDE LAP OF VALVE	
98	High Pressure, inches	.06
102	Low " "	
	BOILER	
113	Type	Belpaire, Wide Firebox
114	Outside Diam. 1st Ring	71.16
	TUBES	
115	Number	373
116	Outside Diam., inches	2
	Pitch "	2.6875
118	Length Between Tube Sheets, inches	164.28
119	Total Fire Area, sq. ft.	6.23
124	Boiler Pressure, pounds	205
	SUPERHEATER	
125	Number of Tubes	—
126	Outside Diam. " inches	—
128	Length of " "	—
	FIREBOX, INSIDE, INCHES	
132	Length	118.32
133	Width	65.04
137	Air Inlets to Ashpan, sq. ft.	7.56
	GRATES	
144	Type	Rocking Finger
145	Grate Area, sq. ft.	48.66
146	Area of Dead Grates	0

	HEATING SURFACE, SQUARE FEET	
154	Of the Tubes, Water Side	2673.68
155	" " " Fire "	2339.23
156	" " Firebox, " "	166.06
157	" " Superh'r, " "	—
*158	Total, Based on " "	2505.29
159	" " " " " of Firebox and Water Side of Tubes	2839.74
	BOILER VOLUME WITH WATER SURFACE AT LEVEL OF 2D GAGE COCK	
160	Water Space, cu. ft.	349.7
161	Steam " " "	83.1
	EXHAUST NOZZLE	
162	Double or Single	Single
163	Size, inches	5.63
167	Area, sq. inches	24.89
	REVERSE LEVER	
168	H. P. Notches Forward of Center	22
169	L. P. Notches Forward of Center	—
	RATIOS	
171	Heating Surface (158) to Grate Area (145)	51.49
172	Fire Area Thru Tubes (119) to Grate Area (145)	.13
173	Firebox Heating Surface (156) to Grate Area (145)	3.41
174	Tube Heating Surface (155) to Fire Box Heating Surface (156)	14.09

*USED IN CALCULATIONS

Table 9.
Dimensions of H6b class locomotive 2860.

M. P. 394 A —Sixth Sheet

PENNSYLVANIA RAILROAD COMPANY

Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company

TEST DEPARTMENT

AVERAGE RESULTS OF LOCOMOTIVE TESTS

LOCOMOTIVE:
TYPE 2-8-0
CLASS H6b
NUMBER 2860

FUEL Jamison Coal

SUBJECT: Self Cleaning Front End

ALTOONA, PA., 6-29-1910

TEST NUMBER	RUNNING CONDITIONS: TEST DESIGNATION	Duration of Test, Hours	Miles per Hour	Throttle Opening, Full or Partial	Actual Cut-off Per Cent., H. P. Cylinders	Draft in Firebox	BOILER PERFORMANCE: Pressure in Boiler, Lbs. per Sq. Inch	Draft in Smoke Box, Inches of Water	Draft in Ash Pan, Inches of Water	Calorific Value of Dry Fuel, B. T. U. per Lb.	Cinders Collected in Smoke Box, Pounds per Hour
	R. P. M. Cut-off Throttle	196	199	203	208 to 271		217	222	225	248	238
1200.276	80-20-F	2.25	13.00	Full	19.2	0.7	204.6	1.3	0.1	13176	21
1200.271	80-30-F	3.00	13.00	"	31.4	1.1	204.6	2.6	0.1	13176	26
1200.272	80-40-F	2.50	13.00	"	38.9	1.6	204.8	3.4	0.1	13176	31
1200.275	120-40-F	2.00	19.50	"	38.9	1.9	204.5	5.2	0.2	14137	79
1200.286	140-40-F	.75	22.75	"	13.9	2.1	200.5	5.8	0.1	14137	436

TEST NUMBER	BOILER PERFORMANCE: Dry Fuel Fired per Hour, Pounds	Dry Fuel per Hour, Pounds per Sq. Ft. of Grate	Water Delivered to Boiler, Pounds per Hour	Equivalent Evaporation from and at 212° F., Pounds: Per Hour	Per Hour per Sq. Ft. of Fire Heating Sur.	Per Pound of Dry Fuel	Boiler Horse Power (34½ U. of E.)	Efficiency of Boiler, Based on Fuel	Draft Back of Diaph.	ENGINE PERFORMANCE: Pressure in Branch Pipe, Pounds per Sq. In.	Superheat in Branch Pipe, Degrees F.
	338	339	340	344	345	347	349	350		220	230
1200.276	1734	35.64	13890	16669	6.65	9.61	483.2	70.44	1.1		
1200.271	2593	53.29	19628	23750	9.48	9.16	688.4	67.14	2.3		
1200.272	3289	67.59	24036	29104	11.62	8.85	843.6	64.87	3.0		
1200.275	4950	101.73	31111	37632	15.02	7.60	1090.7	51.92	4.6		
1200.286	6336	130.21	33188	39989	15.96	6.31	1159.1	43.11	5.2		

TEST NUMBER	ENGINE PERFORMANCE: Dry Steam to Engines, Pounds per Hour	Indicated Horse Power	Dry Fuel per Indicated Horse Power Hour, Pounds	Dry Steam per Indicated Horse Power Hour, Pounds	Front End	LOCOMOTIVE PERFORMANCE: Drawbar Pull, Pounds	Dynamometer or Drawbar Horse Power	Dry Fuel per Dynamom. Horse Power Hour, Pounds	Dry Steam per Dynamom. Horse Power Hour, Pounds	Machine Efficiency of Locomotive, Per Cent.	Thermal Efficiency of Locomotive, per Cent., (Based on Fuel)	Exhaust Nozzle Diameter
	214	379	380	381		265	383	384	385	398	399	
1200.276	13061	520.2	3.3	25.11	Fig.20	12014	428.5	4.1	30.48	82.4	4.75	5.5
1200.271	19387	817.6	3.2	23.71	"	20234	701.4	3.7	27.64	85.8	5.22	"
1200.272	23723	963.5	3.4	24.62	"	24526	850.2	3.9	27.90	88.2	4.99	"
1200.275	30723	1252.8	4.0	24.52	"	20998	1091.8	4.5	28.14	87.1	3.97	"
1200.286	32786	1308.4	4.8	25.06	"	18771	1138.7	5.6	28.79	87.0	3.24	"

Table 10.

Results of tests of standard front end, H6b class locomotive.

M. P. 394 A—Sixth Sheet
8 x 10½

11-9-10

PENNSYLVANIA RAILROAD COMPANY

Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company

TEST DEPARTMENT

AVERAGE RESULTS OF LOCOMOTIVE TESTS

LOCOMOTIVE:
TYPE 2-8-0
CLASS H6b
NUMBER 2860

FUEL: Jamison Coal

SUBJECT: Self Cleaning Front End

ALTOONA, PA., 6-29-1910

TEST NUMBER	RUNNING CONDITIONS: TEST DESIGNATION	Duration of Test, Hours	Miles per Hour	Throttle Opening, Full or Partial	Actual Cut-off Per Cent., H. P. Cylinders	Draft In Firebox	BOILER PERFORMANCE: Pressure in Boiler, Lbs. per Sq. Inch	Draft in Smoke Box, Inches of Water	Draft in Ash Pan, Inches of Water	Calorific Value of Dry Fuel, B. T. U. per Lb.	Cinders Collected in Smoke Box, Pounds per Hour
	R. P. M. Cut-off Throttle	196	199	203	268 to 271		217	222	225	248	238
1200.423	80-20-F	2.0	12.86	Full		0.6	204.6	1.4	0.0	12928	5
1200.422	80-30-F	2.0	12.86	"		0.8	203.7	2.1	0.2	"	8
1200.424	80-40-F	2.0	12.86	"		1.2	204.3	3.3	0.1	"	16
1200.425	120.40-F	2.0	19.30	"		2.1	201.4	5.2	0.2	"	25
1200.428	120-40-F	1.5	19.30	"		1.5	202.0	5.6	0.2	13390	0
1200.426	120-45-F	1.0	19.30	"		2.3	159.9	5.6	0.2	12928	29
1200.427	120-45-F	1.0	19.30	"		2.4	201.6	5.7	0.1	13390	29

TEST NUMBER	BOILER PERFORMANCE: Dry Fuel Fired per Hour, Pounds	Dry Fuel per Hour, Pounds per Sq. Ft. of Grate	Water Delivered to Boiler, Pounds per Hour	Equivalent Evaporation from and at 212° F., Pounds: Per Hour	Per Hour per Sq. Ft. of Fire Heating Sur.	Per Pound of Dry Fuel	Boiler Horse Power (34½ U. of E.)	Efficiency of Boiler, Based on Fuel	Draft Back of Diaph.	ENGINE PERFORMANCE: Pressure in Branch Pipe, Pounds per Sq. In.	Superheat in Branch Pipe Degrees F.
	338	'339	340	344	345	347	349	350		220	230
1200.423	1921	39.48	14658	17781	7.10	9.26	515.4	69.18	1.2		
1200.422	2381	48.93	17766	21530	8.59	9.04	624.1	67.54	1.9		
1200.424	3264	67.08	23315	28390	11.33	8.70	822.9	65.00	3.0		
1200.425	5017	103.11	30430	37175	14.84	7.41	1077.5	55.36	4.6		
1200.428	5133	105.48	31236	38192	15.25	7.44	1107.0	53.66	4.8		
1200.426	5323	109.40	31253	38119	15.21	7.16	1104.7	53.49	4.8		
1200.427	5301	108.93	32438	39625	15.82	7.48	1148.5	53.95	5.1		

TEST NUMBER	ENGINE PERFORMANCE: Dry Steam to Engines, Pounds per Hour	Indicated Horse Power	Dry Fuel per Indicated Horse Power Hour, Pounds	Dry Steam per Indicated Horse Power Hour, Pounds	Front End	LOCOMOTIVE PERFORMANCE: Drawbar Pull, Pounds	Dynamometer or Drawbar Horse Power	Dry Fuel per Dynamom. Horse Power Hour, Pounds	Dry Steam per Dynamom. Horse Power Hour, Pounds	Machine Efficiency of Locomotive, Per Cent.	Thermal Efficiency of Locomotive, per Cent. (Based on Fuel)	Exhaust Nozzle Diameter
	214	379	380	381		265	383	384	385	398	399	
1200.423	14275				Fig. 22	14282	489.9	3.92	29.14		5.02	5.50
1200.422	17501				"	18695	641.3	3.71	27.29		5.31	"
1200.424	22937				"	24580	843.2	3.87	27.20		5.09	"
1200.425	30062				"	20316	1047.7	4.79	28.69		4.11	"
1200.428	30897				"	20600	1060.0	4.84	29.15		3.93	"
1200.426	30875				"	20472	1053.4	5.05	29.31		3.90	"
1200.427	32046				"	21164	1089.0	4.87	29.43		3.90	"

Table 11.
Results of tests of baffle plate front end, H6b class locomotive.

M. P. 394 A—Sixth Sheet
8 x 10½

11-6-10

PENNSYLVANIA RAILROAD COMPANY

Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company

TEST DEPARTMENT

AVERAGE RESULTS OF LOCOMOTIVE TESTS

LOCOMOTIVE:
TYPE 2-8-0
CLASS H8b
NUMBER 2860

FUEL: Jamison Coal

SUBJECT: Self Cleaning Front End

ALTOONA, PA., 6-29-1910

TEST NUMBER	RUNNING CONDITIONS: TEST DESIGNATION	Duration of Test, Hours	Miles per Hour	Throttle Opening, Full or Partial	Actual Cut-off Per Cent., H. P. Cylinders	Draft In Firebox	BOILER PERFORMANCE: Pressure in Boiler, Lbs. per Sq. Inch	Draft in Smoke Box, Inches of Water	Draft in Ash Pan, Inches of Water	Calorific Value of Dry Fuel, B. T. U. per Lb.	Cinders Collected in Smoke Box, Pounds per Hour
	R. P. M. Cut-off Throttle	196	199	203	268 to 271		217	222	225	248	238
1200.436	80-20-F	1.0	12.86	Full		0.4	151.9	0.9	No Record	13390	39
1200.435	80-40-F	2.0	12.86	"		1.2	204.0	3.0	0.1	13390	0
1200.437	120.40-F	1.5	19.30	"		1.6	179.4	4.1	0.2	12444	75
1200.447	120-40-F	1.5	19.23	"		2.1	200.4	4.7	0.1	14315	88
1200.448	120-45-F	1.0	19.23	"		2.4	188.3	5.1	0.2	14315	136

TEST NUMBER	BOILER PERFORMANCE: Dry Fuel Fired per Hour, Pounds	Dry Fuel per Hour, Pounds per Sq. Ft. of Grate	Water Delivered to Boiler, Pounds per Hour	Equivalent Evaporation from and at 212° F., Pounds: Per Hour	Per Hour per Sq. Ft. of Fire Heating Sur.	Per Pound of Dry Fuel	Boiler Horse Power (34½ U. of E.)	Efficiency of Boiler, Based on Fuel	Draft Back of Diaph.	ENGINE PERFORMANCE: Pressure in Branch Pipe, Pounds per Sq. In.	Superheat in Branch Pipe Degrees F.
	338	339	340	344	345	347	349	350		220	230
1200.436	1712	35.18	13312	16147	6.45	9.43	468.0	68.02	0.8		
1200.435	3346	68.77	23467	28492	11.37	8.52	825.9	61.45	2.8		
1200.437	4547	93.44	28258	34356	13.71	7.56	995.8	58.67	3.6		
1200.447	5363	110.21	30642	37242	14.87	6.95	1079.5	46.89	4.4		
1200.448	5947	122.20	31208	38004	15.17	6.39	1101.5	43.11	4.9		

TEST NUMBER	ENGINE PERFORMANCE: Dry Steam to Engines, Pounds per Hour	Indicated Horse Power	Dry Fuel per Indicated Horse Power Hour, Pounds	Dry Steam per Indicated Horse Power Hour, Pounds	Front End	LOCOMOTIVE PERFORMANCE: Drawbar Pull, Pounds	Dynamometer or Drawbar Horse Power	Dry Fuel per Dynamom. Horse Power Hour, Pounds	Dry Steam per Dynamom. Horse Power Hour, Pounds	Machine Efficiency of Locomotive, Per Cent.	Thermal Efficiency of Locomotive, per Cent., (Based on Fuel)	Exhaust Nozzle Diameter
	214	379	380	381		265	383	384	385	398	399	
1200.436	13151				Fig.23	9907	339.8	5.04	38.71		3.77	5.625
1200.435	23104				"	24819	851.4	3.93	27.14		4.84	"
1200.437	27916				"	18228	937.9	4.85	29.76		4.22	"
1200.447	30252				"	21015	1077.6	4.98	28.07		3.57	"
1200.448	30830				"	20862	1069.7	5.56	28.82		3.20	"

Table 12.
Results of tests of Buffalo front end, H6b class locomotive.

M. P. 394 A—Sixth Sheet
8 x 10½

11-9-10

Pennsylvania Railroad Company

Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company

TEST DEPARTMENT

Average Results of Locomotive Tests

LOCOMOTIVE:
TYPE 2-8-0
CLASS H6b
NUMBER 2860

FUEL: Jamison Coal

SUBJECT: Self Cleaning Front End.

ALTOONA, PA., 6-29-1910

TEST NUMBER	RUNNING CONDITIONS						BOILER PERFORMANCE				
	TEST DESIGNATION	Duration of Test, Hours	Miles per Hour	Throttle Opening, Full or Partial	Actual Cut-off Per Cent., H. P. Cylinders	Draft In Firebox	Pressure in Boiler, Lbs. per Sq. Inch	Draft in Smoke Box, Inches of Water	Draft in Ash Pan, Inches of Water	Calorific Value of Dry Fuel, B. T. U. per Lb.	Cinders Collected in Smoke Box, Pounds per Hour
	R. P. M. Cut-off Throttle	196	199	203	268 to 271		217	222	225	248	238
1200.441	80-20-F	2	12.82	Full		0.6	204.9	1.5	No	12444	16
1200.438	80-40-F	2	12.82	"		1.8	203.5	3.3	Record	"	22
1200.439	120-40-F	2	19.23	"		1.9	182.4	4.6	"	"	51
1200.442	120-40-F	1	19.23	"		1.3	165.4	3.5	"	"	67
1200.440	120-43-F	1	19.23	"		1.9	178.9	5.0	.1	"	11

TEST NUMBER	BOILER PERFORMANCE									ENGINE PERFORMANCE	
	Dry Fuel Fired per Hour, Pounds	Dry Fuel per Hour, Pounds per Sq. Ft. of Grate	Water Delivered to Boiler, Pounds per Hour	Equivalent Evaporation from and at 212° F., Pounds: Per Hour	Equivalent Evaporation: Per Hour per Sq. Ft. of Fire Heating Sur.	Equivalent Evaporation: Per Pound of Dry Fuel	Boiler Horse Power (34½ U. of E.)	Efficiency of Boiler, Based on Fuel	Draft Back of Diaph.	Pressure in Branch Pipe, Pounds per Sq. In.	Superheat in Branch Pipe Degrees F.
	338	339	340	344	345	347	349	350		220	230
1200.441	1982	40.73	14785	17927	7.16	9.05	519.6	70.23	1.3		
1200.438	3468	71.27	23681	23758	11.40	8.29	833.6	64.34	3.7		
1200.439	4564	93.79	28291	34419	13.74	7.54	997.6	58.52	4.0		
1200.442	4272	87.80	25508	30957	12.35	7.25	897.3	56.26	2.8		
1200.440	4657	95.71	29820	36302	14.49	7.80	1052.3	60.54	4.0		

TEST NUMBER	ENGINE PERFORMANCE					LOCOMOTIVE PERFORMANCE						
	Dry Steam to Engines, Pounds per Hour	Indicated Horse Power	Dry Fuel per Indicated Horse Power Hour, Pounds	Dry Steam per Indicated Horse Power Hour, Pounds	Front End	Drawbar Pull, Pounds	Dynamometer or Drawbar Horse Power	Dry Fuel per Dynamom. Horse Power Hour, Pounds	Dry Steam per Dynamom. Horse Power Hour, Pounds	Machine Efficiency of Locomotive, Per Cent.	Thermal Efficiency of Locomotive, per Cent., (Based on Fuel)	Exhaust Nozzle Diameter
	214	379	380	381		265	383	384	385	398	399	
1200.441	14561				Fig. 24	14920	510.1	3.89	28.55		5.26	5.625
1200.438	23359				"	24908	851.6	4.07	27.43		5.02	5.625
1200.439	27949				"	18663	957.0	4.77	29.20		4.29	5.625
1200.442	25199				"	16330	852.7	5.01	29.55		4.08	5.50
1200.440	29459				"	19396	994.5	4.68	29.62		4.37	5.625

Table 13.
Results of tests of Sunbury front end, H6b class locomotive.

M. P. 304 A—Sixth Sheet 8 x 10½ 11-9-10

PENNSYLVANIA RAILROAD COMPANY

Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company

TEST DEPARTMENT

AVERAGE RESULTS OF LOCOMOTIVE TESTS

LOCOMOTIVE:
TYPE 2-8-0
CLASS H6b
NUMBER 2860

FUEL: Jamison Coal

SUBJECT: Self Cleaning Front End

ALTOONA, PA., 6-29-1910

TEST NUMBER	RUNNING CONDITIONS: TEST DESIGNATION	Duration of Test, Hours	Miles per Hour	Throttle Opening, Full or Partial	Actual Cut-off Per Cent., H. P. Cylinders	Draft in Firebox	BOILER PERFORMANCE: Pressure in Boiler, Lbs. per Sq. Inch	Draft in Smoke Box, Inches of Water	Draft in Ash Pan, Inches of Water	Calorific Value of Dry Fuel, B. T. U. per Lb.	Cinders Collected in Smoke Box, Pounds per Hour
	R. P. M. Cut-off Throttle	196	199	203	268 to 271		217	222	225	248	238
1200.432	80-20-F	2.0	12.86	Full		0.6	203.3	1.7	0.1	13390	9
1200.452	80-30-F	2.0	12.78	"		1.2	204.9	3.6	0.1	13888	0
1200.429	80-40-F	2.0	12.86	"		1.1	204.5	4.0	0.1	13390	4
1200.451	100-45-F	1.5	15.98	"		2.0	203.5	7.3	0.1	13888	11
1200.430	120-40-F	1.5	19.30	"		1.8	195.8	6.3	0.2	13390	8
1200.431	120-45-F	1.0	19.30	"		2.1	203.7	6.9	0.2	13390	12
1200.444	120-45-F	1.0	19.23	"		1.7	190.6	6.1	No	14315	22
1200.445	120-45-F	1.0	19.23	"		2.3	194.6	6.8	Record	14315	23
1200.446	120-45-F	1.0	19.23	"		1.9	204.9	6.8	0.1	14315	17
1200.434	120-50-F	1.0	19.30	"		2.3	191.1	7.4	0.2	13390	11

TEST NUMBER	BOILER PERFORMANCE: Dry Fuel Fired per Hour, Pounds	Dry Fuel per Hour, Pounds per Sq. Ft. of Grate	Water Delivered to Boiler, Pounds per Hour	EQUIVALENT EVAPORATION FROM AND AT 212° F., POUNDS: Per Hour	Per Hour per Sq. Ft. of Fire Heating Sur.	Per Pound of Dry Fuel	Boiler Horse Power (34½ U. of E.)	Efficiency of Boiler, Based on Fuel	Draft Back of Diaph.	ENGINE PERFORMANCE: Pressure in Branch Pipe, Pounds per Sq. In	Superheat in Branch Pipe Degrees F.
	338	339	340	344	345	347	349	350		220	230
1200.432	1923	39.52	14723	17906	7.15	9.31	519.0	67.15	1.1		
1200.452	2700	55.49	21731	26157	10.44	9.69	758.2	67.39	2.6		
1200.429	3333	68.47	23995	29250	11.68	8.78	847.8	63.33	2.6		
1200.451	5222	107.32	33315	40074	16.00	7.67	1161.6	53.34	5.1		
1200.430	5290	108.71	30521	37265	14.87	7.04	1080.1	50.78	4.4		
1200.431	5342	109.78	33098	40376	16.12	7.56	1170.3	54.53	4.7		
1200.444	5473	112.47	31622	38511	15.37	7.04	1116.3	47.50	4.3		
1200.445	5947	122.20	32200	39187	15.64	6.59	1135.8	44.46	5.1		
1200.446	6097	125.29	33722	41006	16.37	6.73	1188.5	45.40	4.9		
1200.434	5345	109.84	34256	41734	16.66	7.81	1209.6	56.33	5.2		

TEST NUMBER	ENGINE PERFORMANCE: Dry Steam to Engines, Pounds per Hour	Indicated Horse Power	Dry Fuel per Indicated Horse Power Hour, Pounds	Dry Steam per Indicated Horse Power Hour, Pounds	Front End	LOCOMOTIVE PERFORMANCE: Drawbar Pull, Pounds	Dynamometer or Drawbar Horse Power	Dry Fuel per Dynamom. Horse Power Hour, Pounds	Dry Steam per Dynamom. Horse Power Hour, Pounds	Machine Efficiency of Locomotive, Per Cent.	Thermal Efficiency of Locomotive, per Cent., (Based on Fuel)	Exhaust Nozzle Diameter
	214	379	380	381		265	383	384	385	398	399	
1200.432	14515				Fig.25	14830	508.8	3.78	28.53		5.03	5.625
1200.452	20972				"	22538	768.3	3.51	27.30		5.22	"
1200.429	23502				"	24889	853.9	3.90	27.52		4.87	"
1200.451	32889				"	26967	1149.1	4.54	28.62		4.04	"
1200.430	30152				"	20156	1037.1	5.10	29.07		3.73	"
1200.431	32698				"	21398	1101.4	4.85	29.70		3.92	"
1200.444	31239				"	20809	1067.0	5.13	29.28		3.47	"
1200.445	31810				"	21427	1098.7	5.41	28.95		3.29	"
1200.446	33207				"	22163	1136.4	5.37	29.22		3.31	"
1200.434	33842				"	21748	1119.1	4.78	30.24		3.98	"

Table 14.

Results of tests of Lines West front end, H6b class locomotive.

GRAPHICAL LOGS OF TESTS.

A graphical log is made for each test to show the conditions at each ten-minute interval, and to indicate any irregularity in the weights of coal and water during the run. These diagrams are on file with the Test Plant records. A few representative ones only being shown here.

M. P. Experimental D-1

12 9 1911
8 x 10½

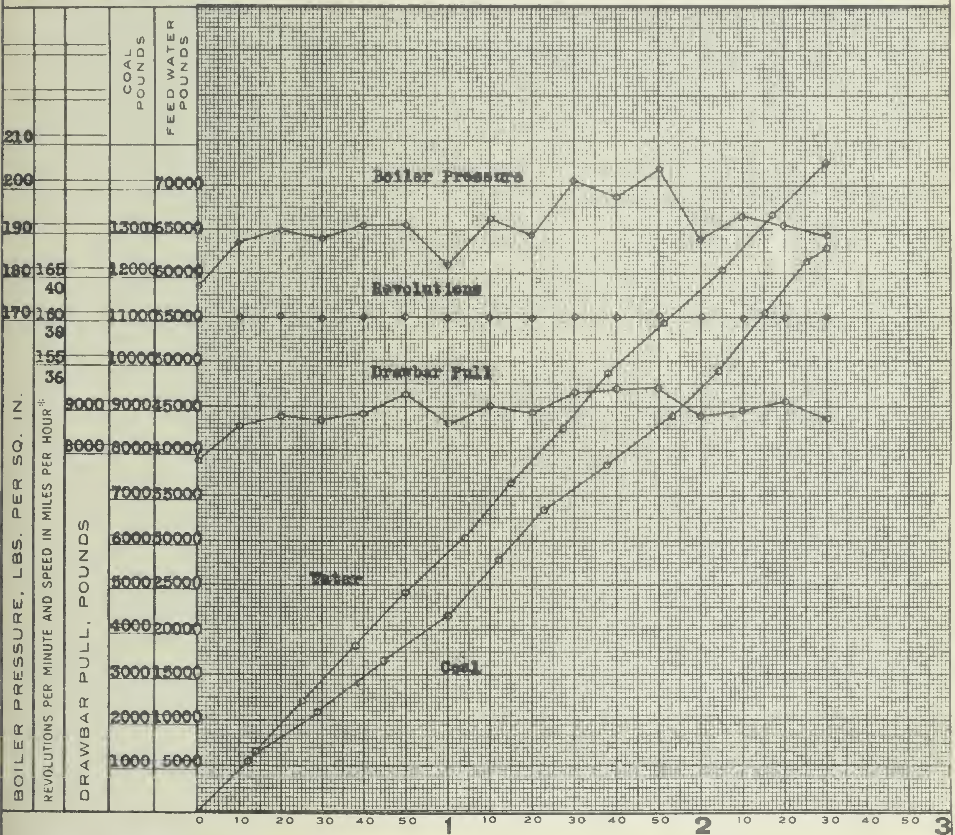
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO P-331 | TEST DEPARTMENT | Bulletin NO 9

GRAPHICAL LOG OF LOCOMOTIVE TEST

Self Cleaning Front End | ALTOONA, PA. 11-28-1912



UPPER FIGURES R. P. M.
LOWER FIGURES APPROX.
SPEED IN MILES PER HOUR

LENGTH OF TEST—MINUTES AND HOURS

LOCOMOTIVE
TYPE 4-4-2
CLASS E2a
NUMBER 5266

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
38.2	160	27	F	5.91

TEST NO. 917

SHEET NO. P-331

M. P. Experimental D-1

12 9 1911
8 x 10½

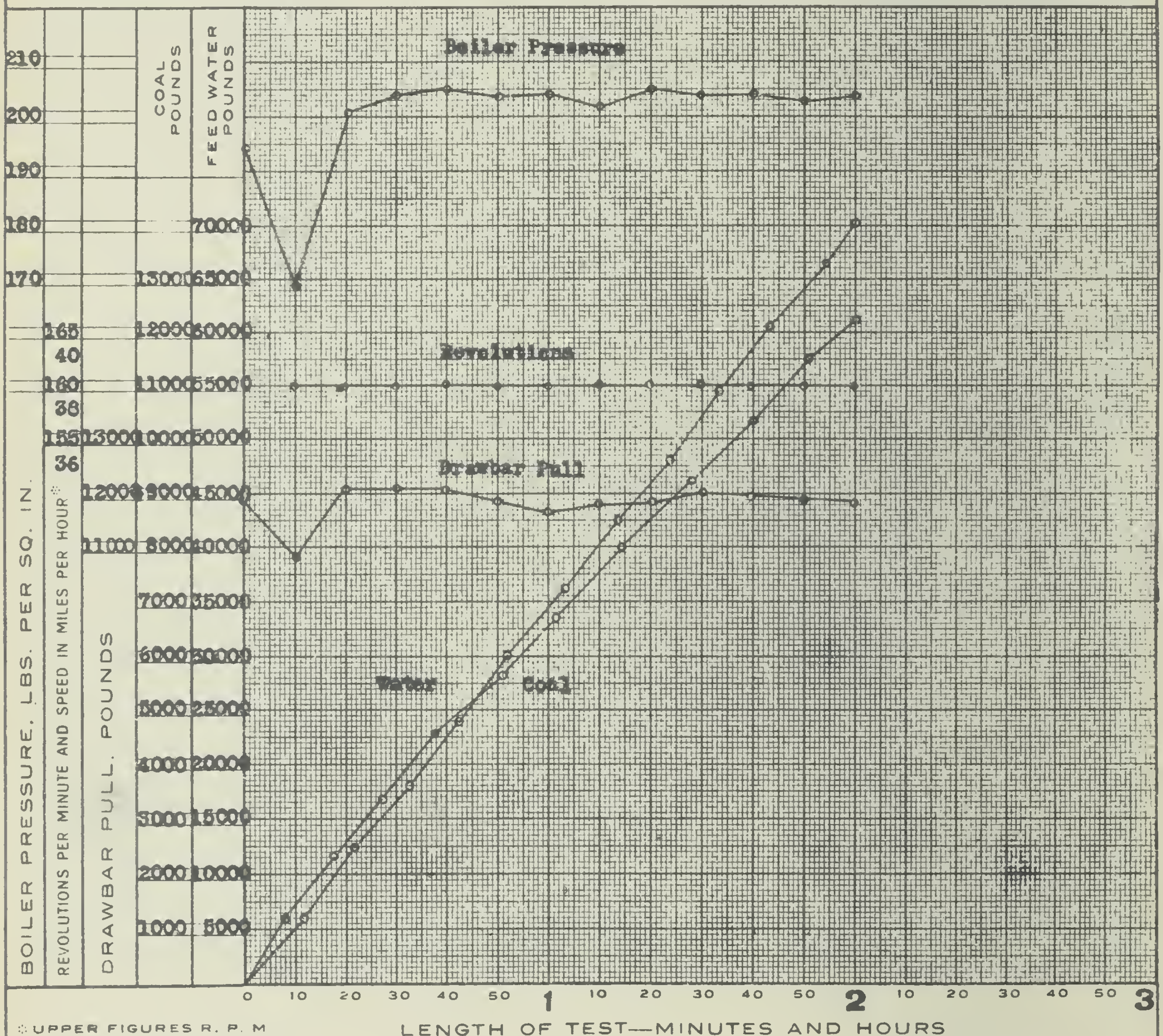
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-332 TEST DEPARTMENT Bulletin NO. 9

GRAPHICAL LOG OF LOCOMOTIVE TEST

Self Cleaning Front End ALTOONA, PA. 7-3-1907



* UPPER FIGURES R. P. M
LOWER FIGURES APPROX.
SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 4-4-2
CLASS E2a
NUMBER 5266

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
38.2	160	32	F	5.76

TEST NO. 900.3

SHEET NO. P-332

M. P. Experimental D-1

12 9 1911
8 x 10½

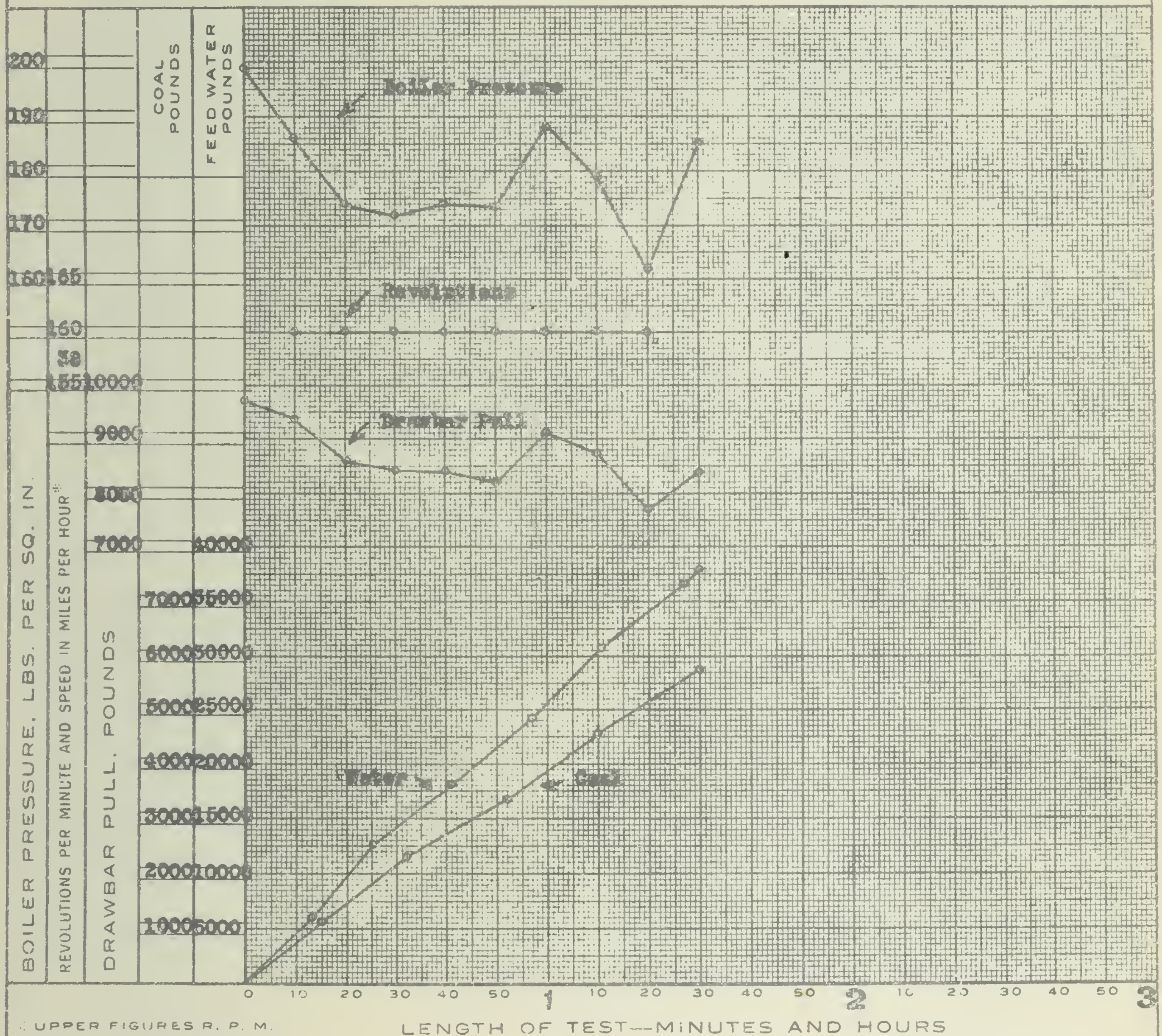
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-333 TEST DEPARTMENT Bulletin NO 9

GRAPHICAL LOG OF LOCOMOTIVE TEST

Self Cleaning Front End ALTOONA PA 8-6-1907



* UPPER FIGURES R. P. M.
LOWER FIGURES APPROX.
SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 4-4-2
CLASS E2a
NUMBER 5266

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
37.6	160	27	Full	6.6

TEST NO. 900.25

SHEET NO. P-333

M. P. Experimental D-1

12 9 1911
8 x 10½

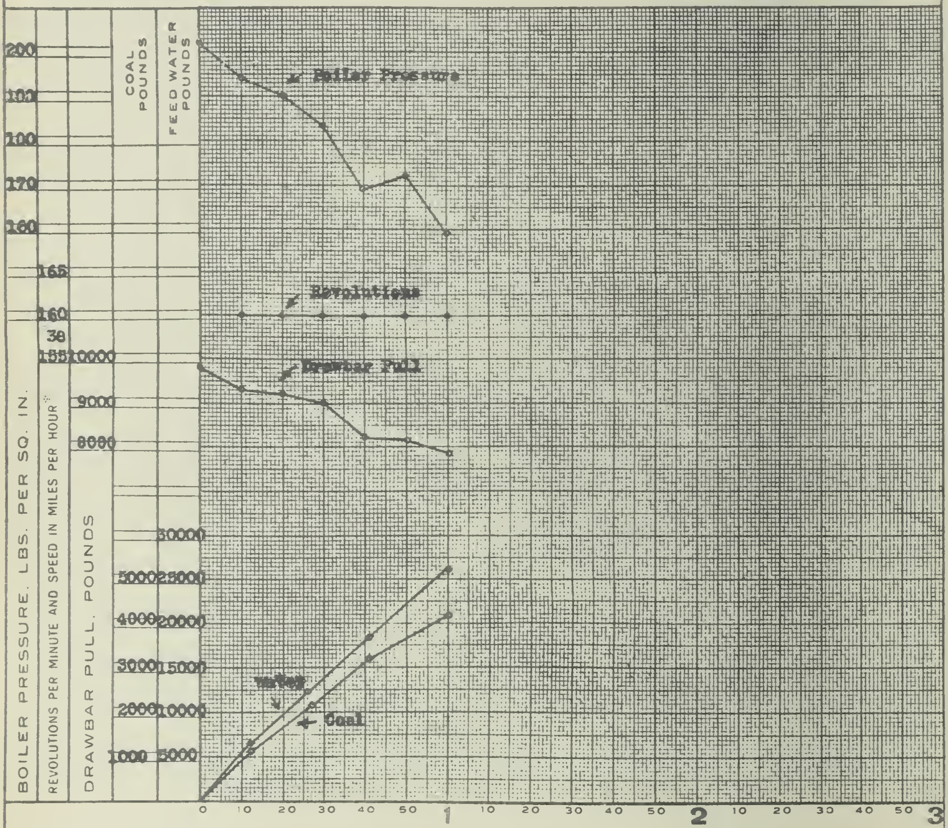
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-334 TEST DEPARTMENT Bulletin NO 9

GRAPHICAL LOG OF LOCOMOTIVE TEST

Self Cleaning Front End ALTOONA, PA. 8-7-1907



* UPPER FIGURES R. P. M
LOWER FIGURES APPROX
SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 4-4-2
CLASS E2a
NUMBER 5266

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
37.6	160	27	Full	6.3

TEST NO. 900.26

SHEET NO. P-334

M. P. Experimental D-1

12 9 1911
8 x 10¼

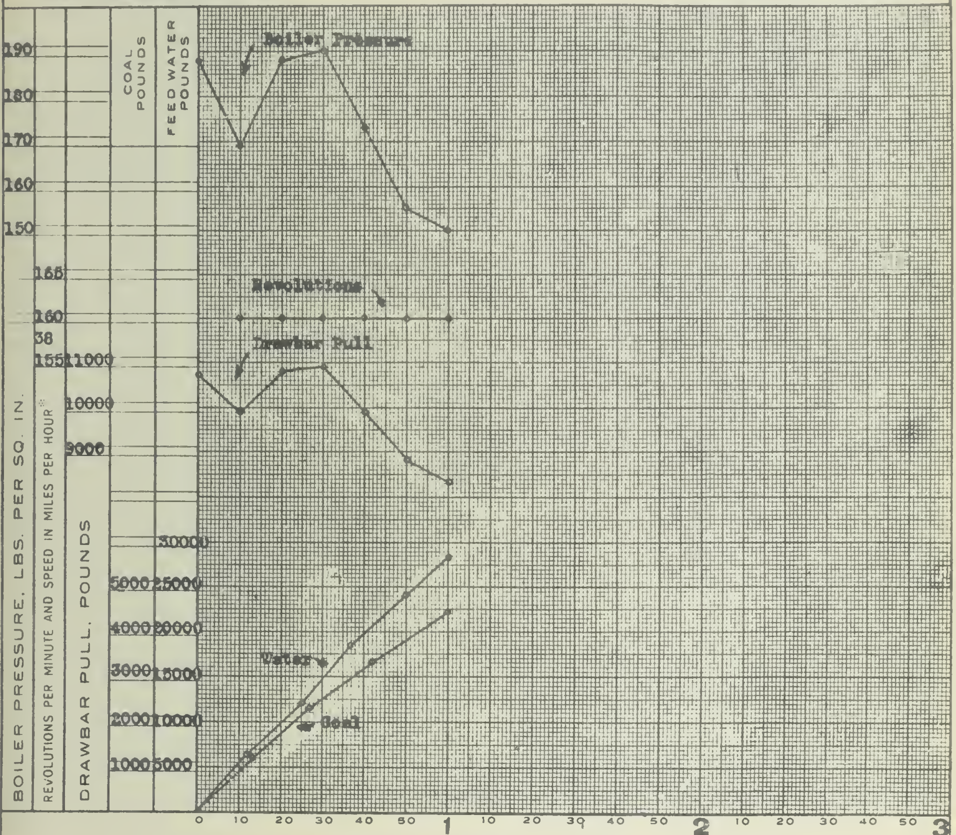
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-335 | TEST DEPARTMENT | Bulletin NO 9

GRAPHICAL LOG OF LOCOMOTIVE TEST

Self Cleaning Front End | ALTOONA, PA. 8-12-1907



* UPPER FIGURES R. P. M
LOWER FIGURES APPROX
SPEED IN MILES PER HOUR

LENGTH OF TEST—MINUTES AND HOURS

LOCOMOTIVE
TYPE 4-4-2
CLASS E2a
NUMBER 5266

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
37.6	160	30	Full	6.4

TEST NO. 900.29

SHEET NO. P-335

M. P. Experimental D-1

12 9 1911
8 x 10½

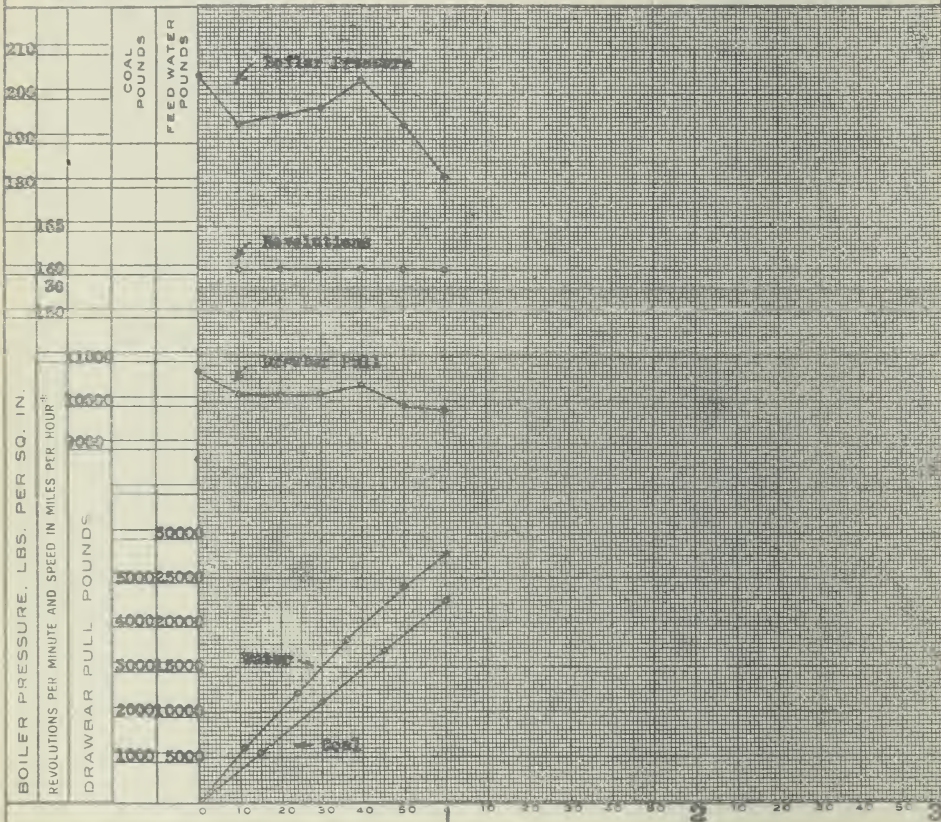
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO P-336 TEST DEPARTMENT Bulletin NO. 9

GRAPHICAL LOG OF LOCOMOTIVE TEST

Self Cleaning Front End ALTOONA, PA. 8-14-1907



LENGTH OF TEST—MINUTES AND HOURS

*UPPER FIGURES R. P. M.
LOWER FIGURES APPROX. SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 4-4-2
CLASS E2a
NUMBER 5266

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
37.6	160	37	Full	6.2

TEST NO. 900.32

SHEET NO. P-336

M. P. Experimental D-1

12 9 1911
8 x 10½

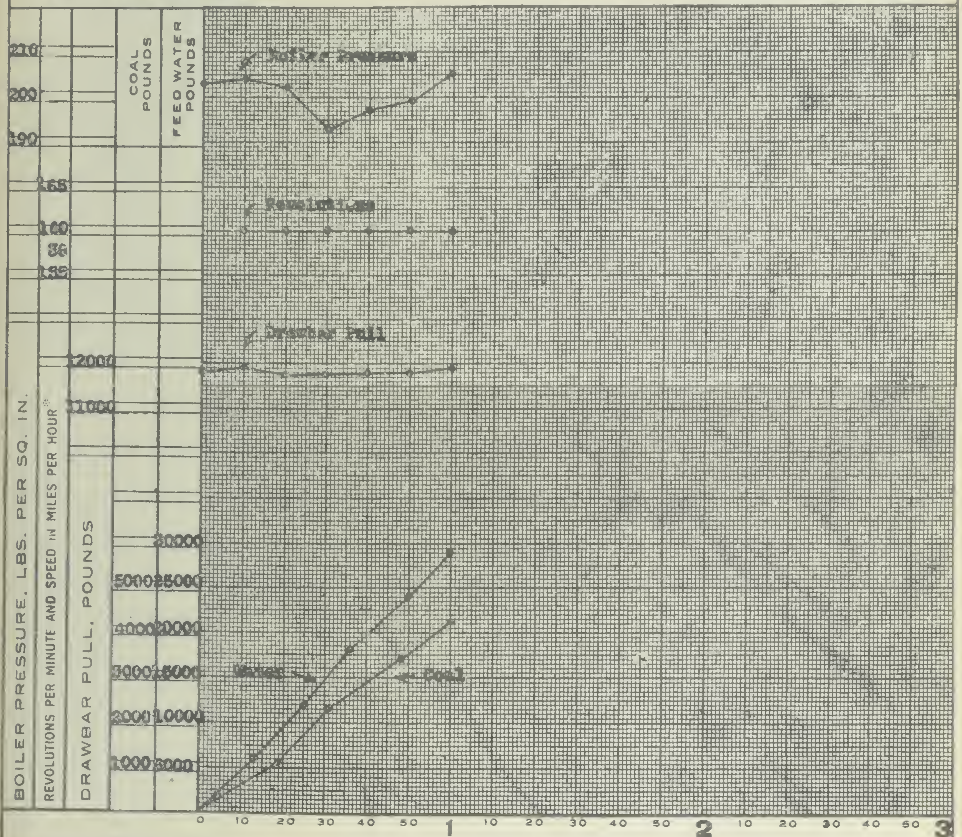
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-337 TEST DEPARTMENT. Bulletin NO. 9

GRAPHICAL LOG OF LOCOMOTIVE TEST

Self Cleaning Front End ALTOONA, PA., 8-23-1907



LENGTH OF TEST—MINUTES AND HOURS

*UPPER FIGURES R. P. M
LOWER FIGURES APPROX
SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 4-4-2
CLASS E2a
NUMBER 5266

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
37.6	160	27	Full	6.9

TEST NO. 900.58

SHEET NO. P-337

M. P. Experimental D-1

12 9 1911
8 x 10½

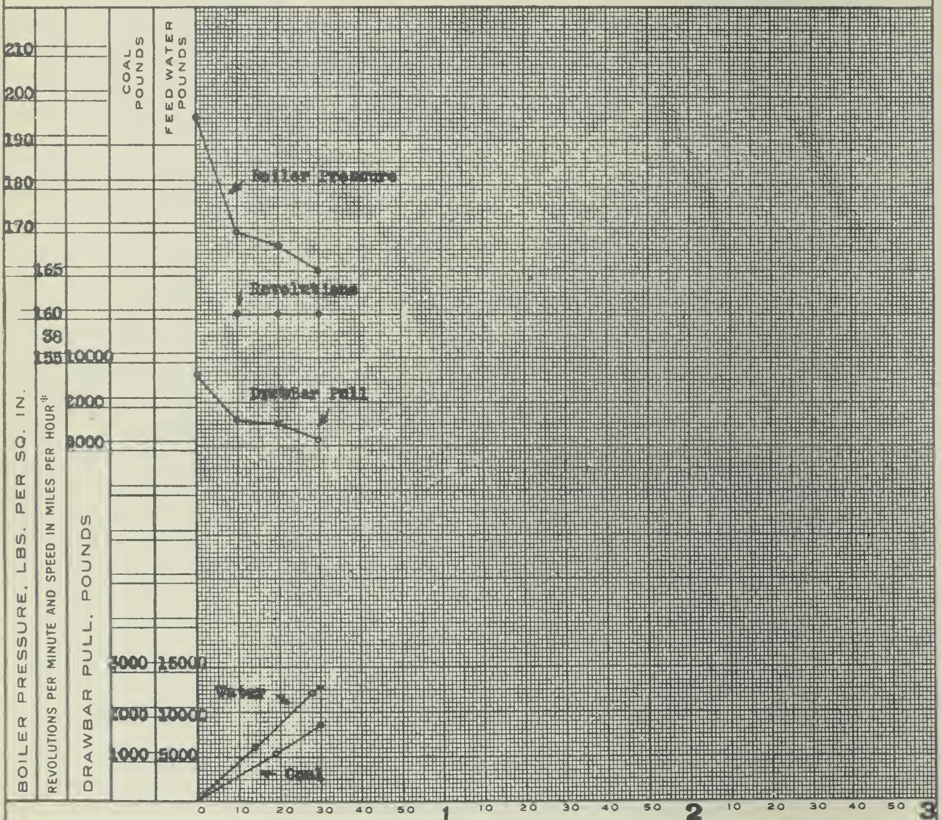
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO P-338 TEST DEPARTMENT Bulletin NO. 9

GRAPHICAL LOG OF LOCOMOTIVE TEST

Self Cleaning Front End ALTOONA, PA., 9-3-1907



*UPPER FIGURES R. P. M
LOWER FIGURES APPROX.
SPEED IN MILES PER HOUR

LENGTH OF TEST—MINUTES AND HOURS

LOCOMOTIVE
TYPE 4-4-2
CLASS E2a
NUMBER 5266

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
37.6	160	27	Full	6.8

TEST NO. 900.40

SHEET NO. P-338

M P. Experimental D-1

12 9 1911
8 x 10½

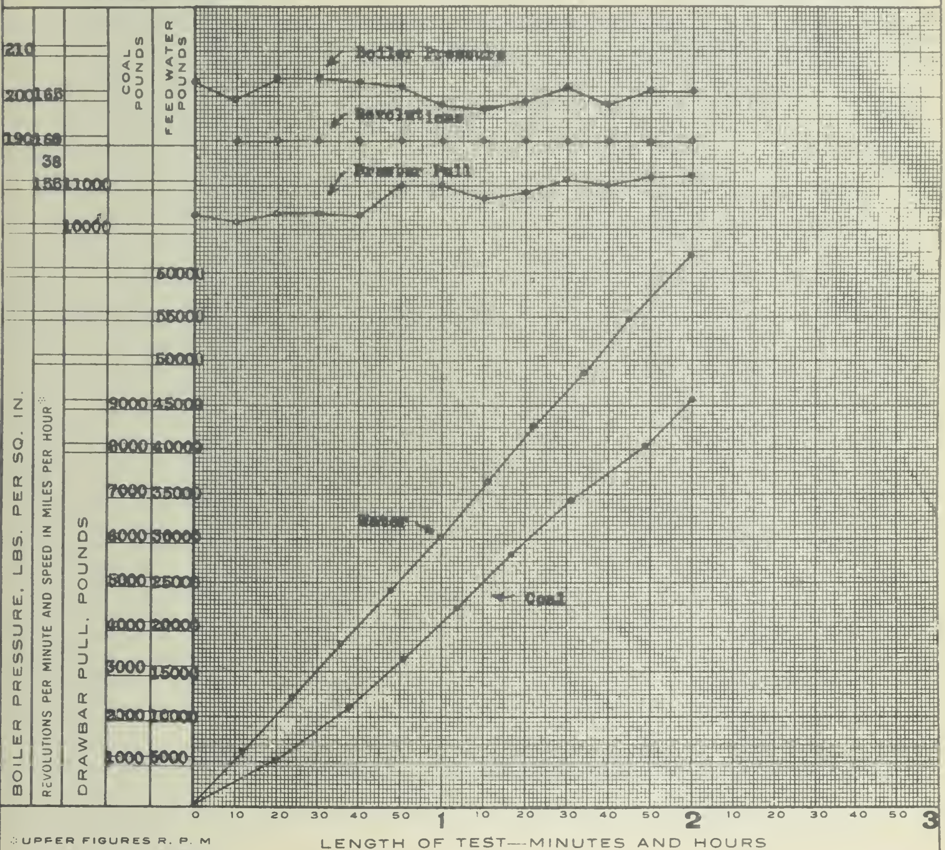
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-339 TEST DEPARTMENT Bulletin NO 9

GRAPHICAL LOG OF LOCOMOTIVE TEST

Self Cleaning Front End ALTOONA, PA., 9-11-1907



UPPER FIGURES R. P. M
LOWER FIGURES APPROX.
SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 4-4-2
CLASS E2a
NUMBER 5266

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
37.6	160	27	Full	6.8

TEST NO. 900.41

SHEET NO. P-339

M. P Experimental D-1

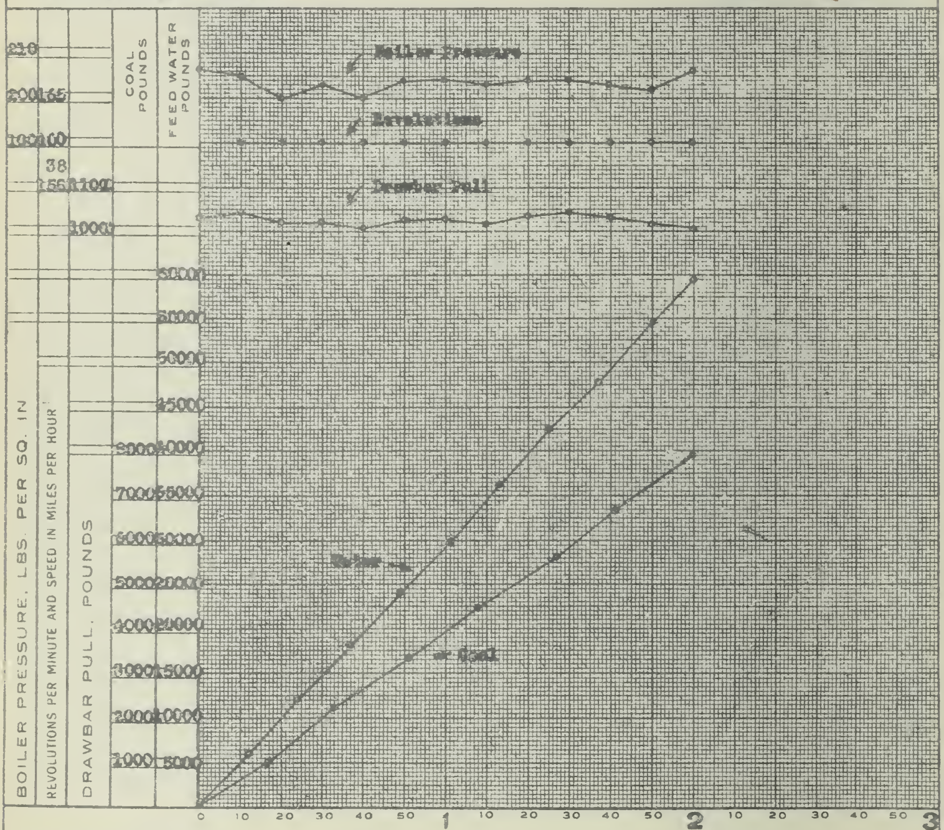
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO P-340 | TEST DEPARTMENT | Bulletin NO. 9

GRAPHICAL LOG OF LOCOMOTIVE TEST

Self Cleaning Front End | ALTOONA PA., 9-12-1907



* UPPER FIGURES R. P. M
LOWER FIGURES APPROX.
SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 4-4-2
CLASS E2a
NUMBER 5266

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
37.6	160	27	Full	7.5

TEST NO. 900.42

SHEET NO. P-340

M. P. Experimental D-1

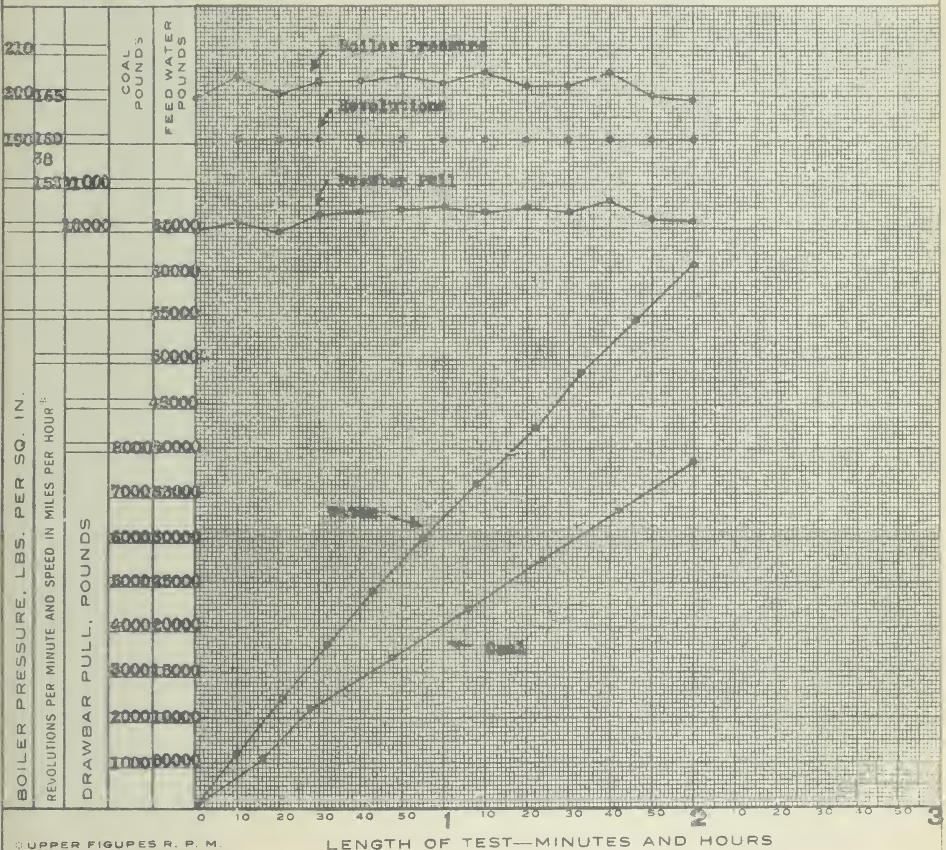
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-341 TEST DEPARTMENT Bulletin NO 9

GRAPHICAL LOG OF LOCOMOTIVE TEST

Self Cleaning Front End ALTOONA PA 9-14-1907



* UPPER FIGURES R. P. M.
LOWER FIGURES APPROX. SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 4-4-2
CLASS E2a
NUMBER 5266

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
37.6	160	27	Full	7.9

TEST NO. 900.44

SHEET NO. P-341

M. P. Experimental D-1

12 9 1911
8 x 10½

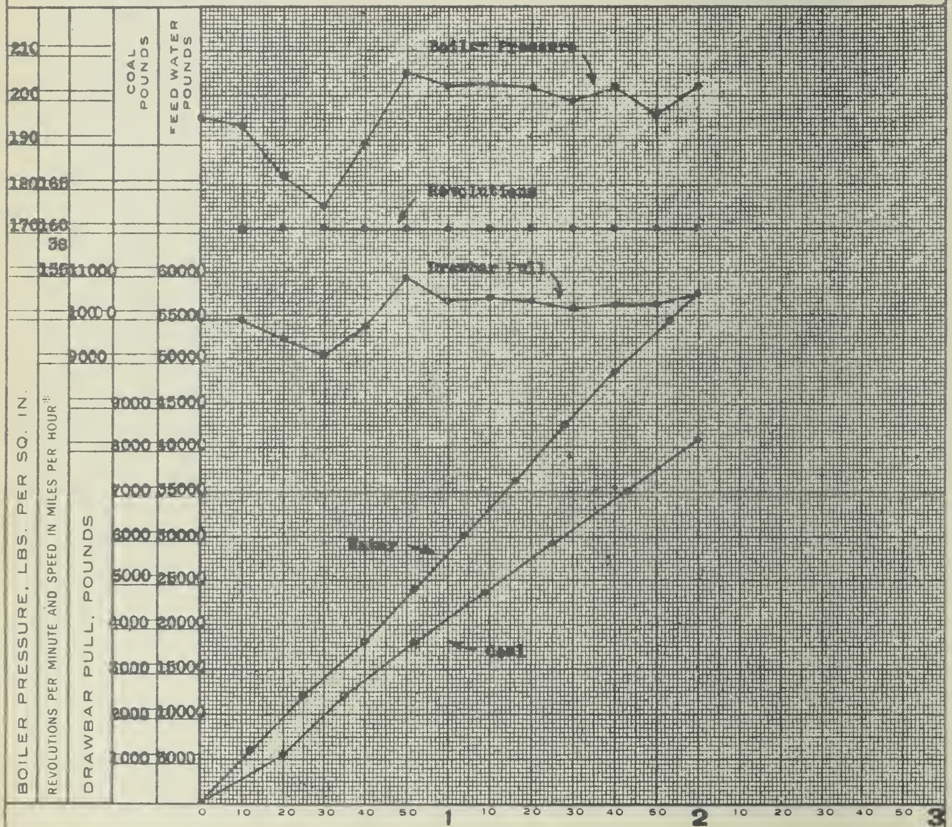
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO P-342 TEST DEPARTMENT Bulletin NO. 9

GRAPHICAL LOG OF LOCOMOTIVE TEST

Self Cleaning Front End ALTOONA, PA. 9-19-1907



UPPER FIGURES R. P. M
LOWER FIGURES APPROX.
SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 4-4-2
CLASS E2a
NUMBER 5266

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
37.6	160	27	F	7.1

TEST NO. 900.47

SHEET NO. P-342

M. P Experimental D-1 12 9 1911 8 x 10½

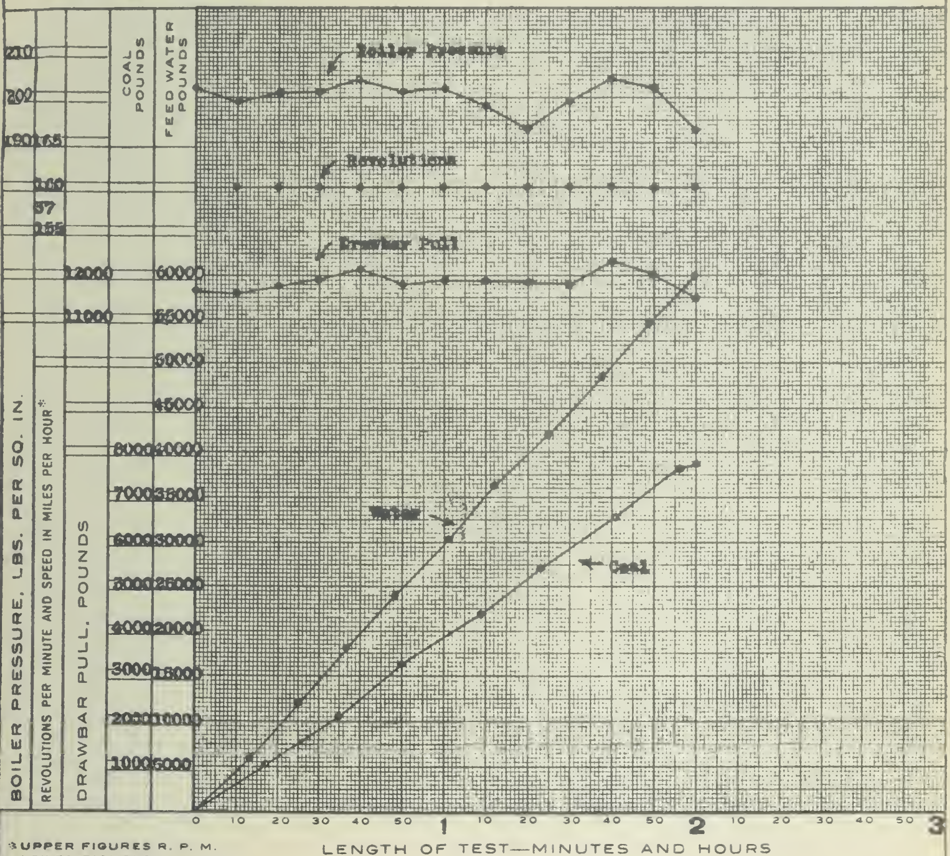
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-343 TEST DEPARTMENT Bulletin NO 9

GRAPHICAL LOG OF LOCOMOTIVE TEST

Self Cleaning Front End ALTOONA PA., 10-25-1907



*UPPER FIGURES R. P. M.
LOWER FIGURES APPROX.
SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 4-4-2
CLASS E3a
NUMBER 2984

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
37.0	160	25	Full	7.8

TEST NO. 1004

SHEET NO. P-343

M. P. Experimental D-1

12 9 1911
8 x 10½

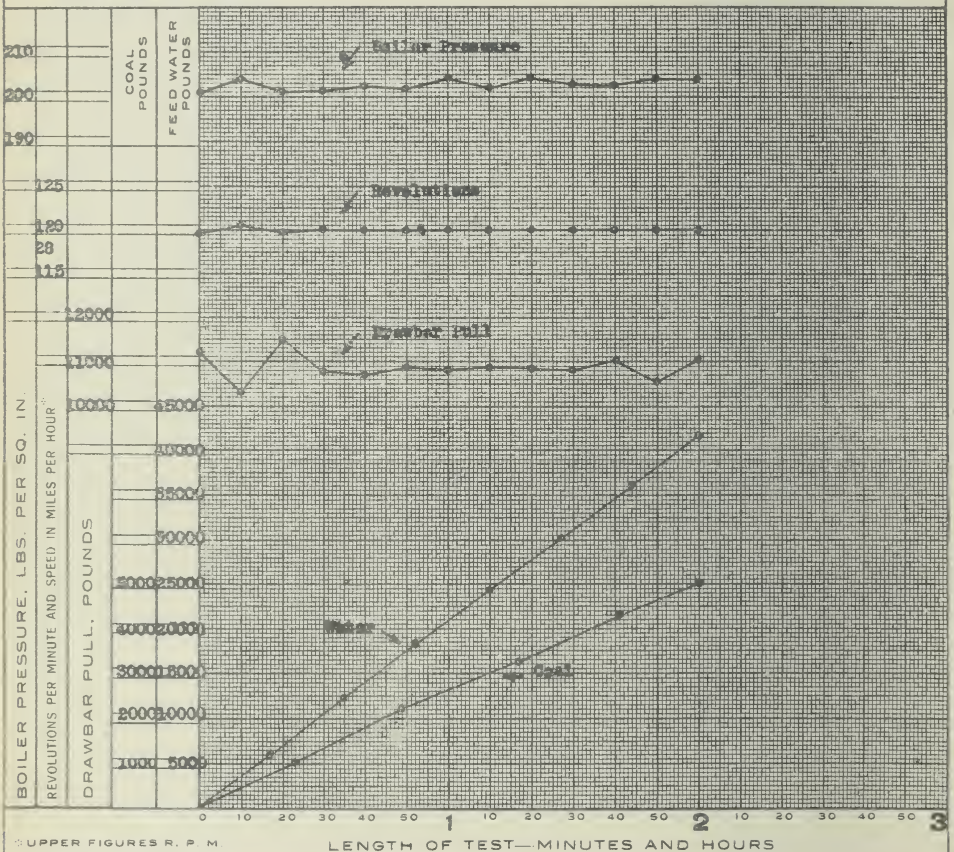
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-344 TEST DEPARTMENT Bulletin NO. 9

GRAPHICAL LOG OF LOCOMOTIVE TEST

Self Cleaning Front End ALTOONA, PA., 10-30-1907



*UPPER FIGURES R. P. M.
LOWER FIGURES APPROX. SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 4-4-2
CLASS E3a
NUMBER 2984

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
27.8	120	20	Full	8.2

TEST NO. 1005

SHEET NO. P-344

M. P. Experimental D-1

12 9 1911
8 x 10½

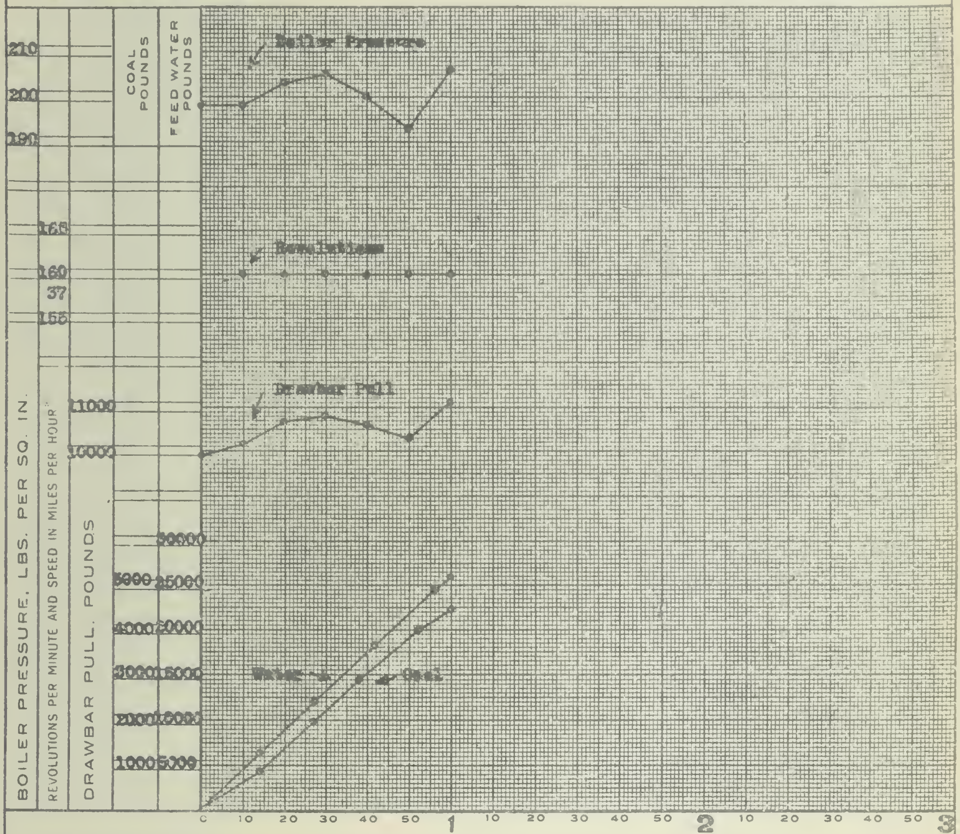
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-345 TEST DEPARTMENT Bulletin NO. 9

GRAPHICAL LOG OF LOCOMOTIVE TEST

Self Cleaning Front End ALTOONA, PA. 11-4-1907



LENGTH OF TEST—MINUTES AND HOURS

*UPPER FIGURES R. P. M.
LOWER FIGURES APPROX
SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 4-4-2
CLASS E3a
NUMBER 2984

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
37.0	160	23	Full	5.8

TEST NO. 1007

SHEET NO. P-345

M. P. Experimental D-1

12 9 1911
8 x 10½

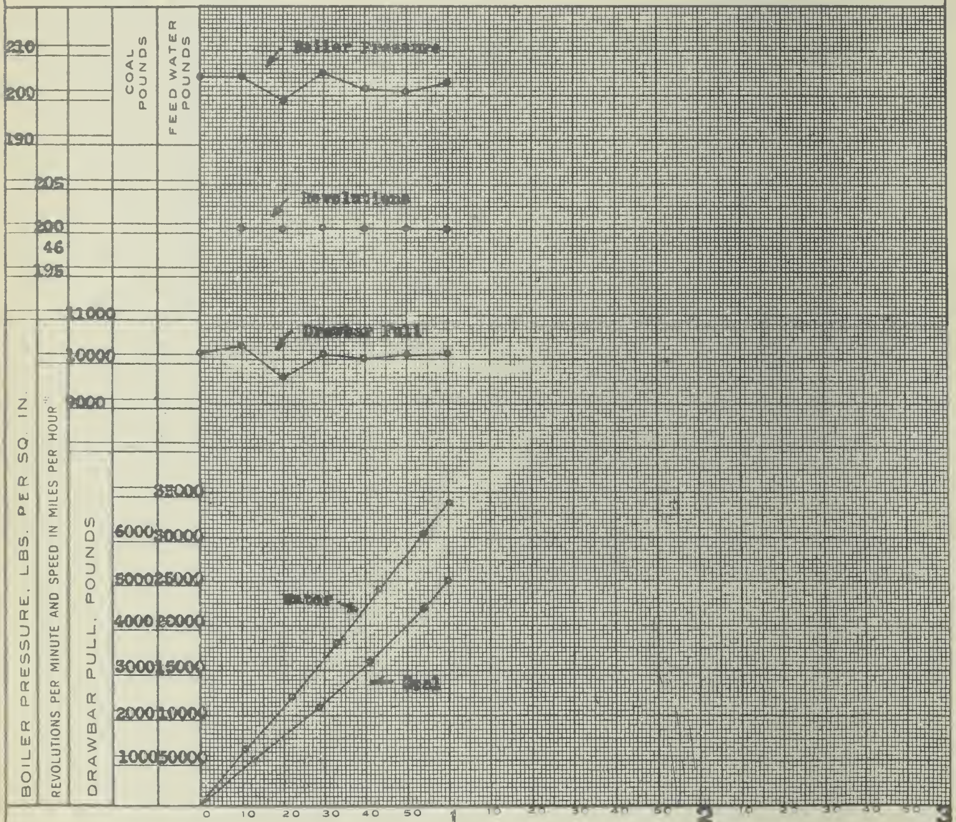
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-346 TEST DEPARTMENT **Bulletin** NO. 9

GRAPHICAL LOG OF LOCOMOTIVE TEST

Self Cleaning Front End ALTOONA, PA., **11-4-1907**



LENGTH OF TEST—MINUTES AND HOURS

* UPPER FIGURES R. P. M.
LOWER FIGURES APPROX
SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 4-4-2
CLASS E3a
NUMBER 2984

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
46.3	200	25	Full	6.6

TEST NO. 1008

SHEET NO. P-346

M P. Experimental D-1

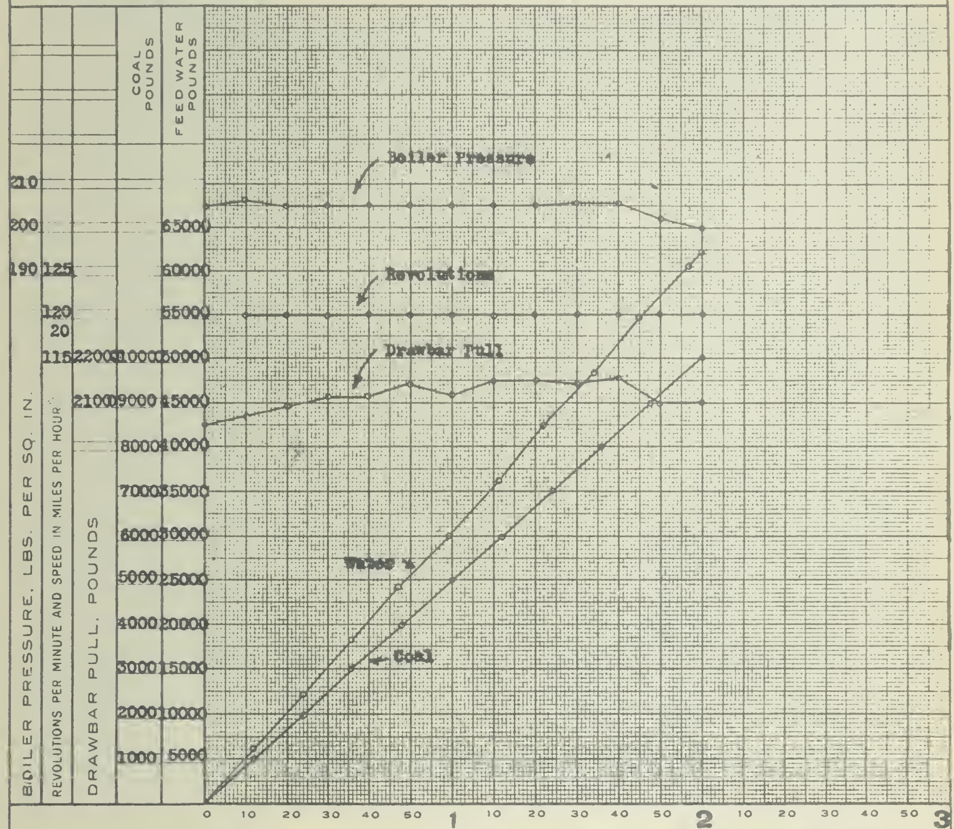
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-347 TEST DEPARTMENT Bulletin NO 9

GRAPHICAL LOG OF LOCOMOTIVE TEST

Self Cleaning Front End ALTOONA PA 5-15-1912



LENGTH OF TEST—MINUTES AND HOURS

*UPPER FIGURES R. P. M
LOWER FIGURES APPROX.
SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 2-8-0
CLASS H6b
NUMBER 2860

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
19.5	120	40	F	6.22

TEST NO. 1200.275

SHEET NO. P-347

M. P. Experimental D-1

13 9 1911
8 x 10½

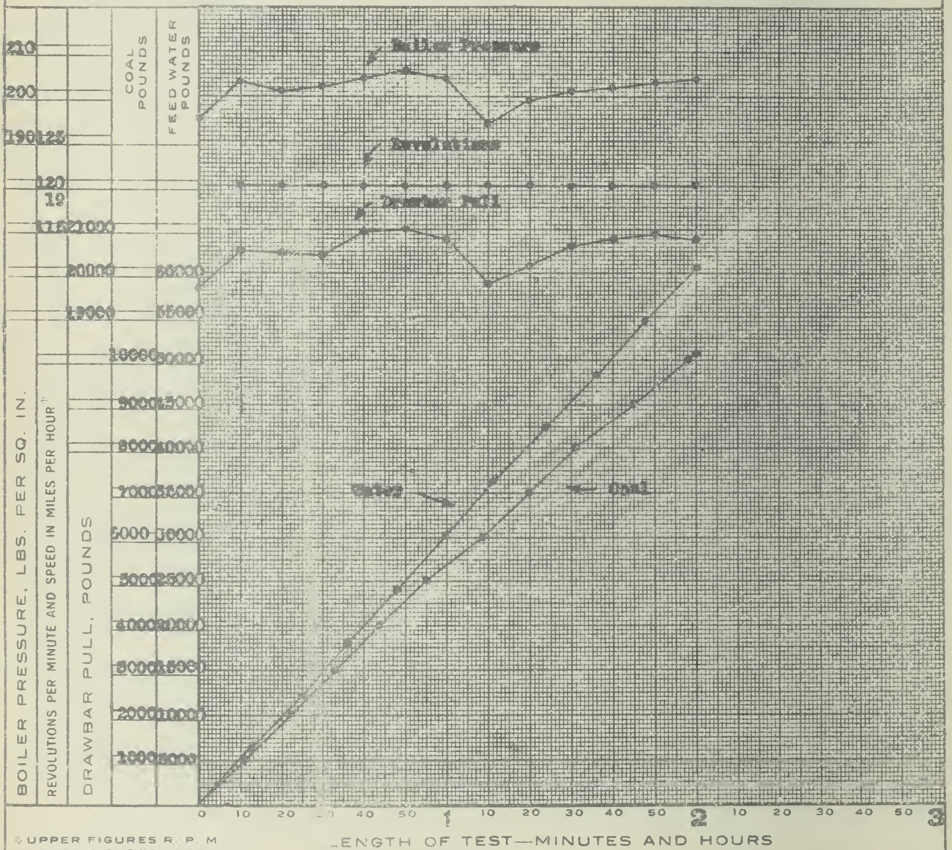
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-348 TEST DEPARTMENT Bulletin NO. 9

GRAPHICAL LOG OF LOCOMOTIVE TEST

Self Cleaning Front End ALTOONA, PA., 1-4-1910



* UPPER FIGURES R. P. M.
LOWER FIGURES APPROX. SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 2-8-0
CLASS H6b
NUMBER 2360

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
19.5	120	40	Full	6.1

TEST NO. 1200.425

SHEET NO. P-348

M. P. Experimental D-1

12 9 1911
8 x 10½

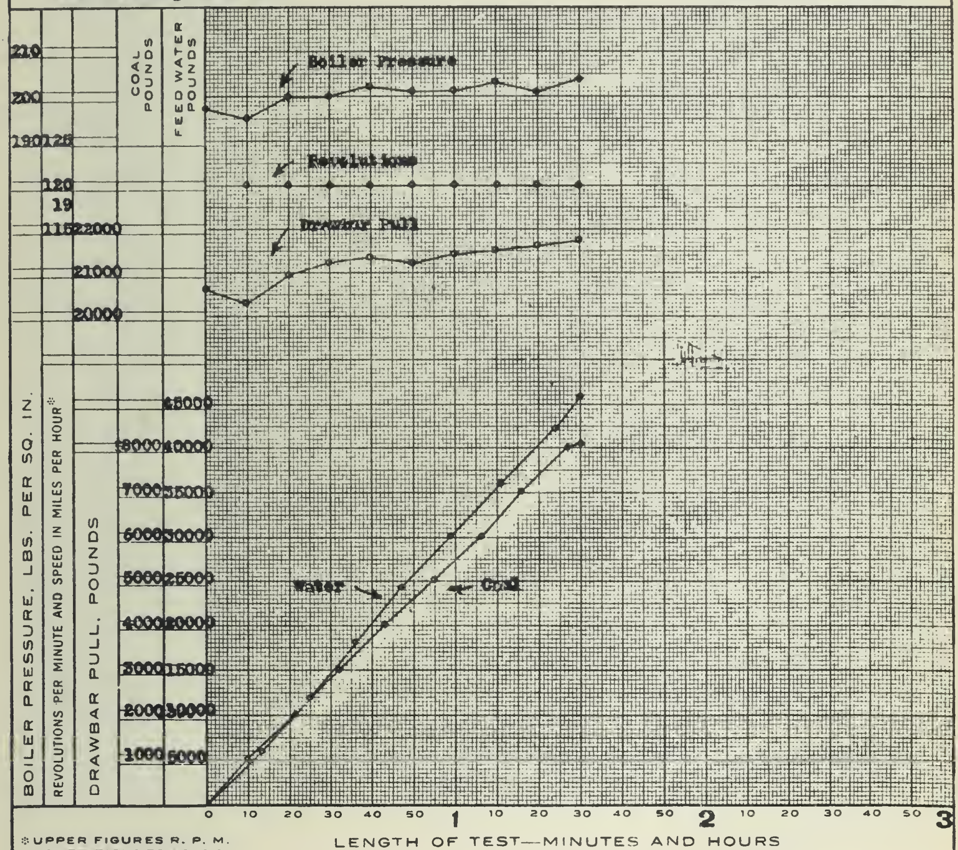
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-349 TEST DEPARTMENT Bulletin NO. 9

GRAPHICAL LOG OF LOCOMOTIVE TEST

Self Cleaning Front End ALTOONA, PA., 2-2-1910



*UPPER FIGURES R. P. M.
LOWER FIGURES APPROX.
SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 2-8-0
CLASS H6b
NUMBER 2860

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
19.2	120	40	Full	5.7

TEST NO 1200.447

SHEET NO. P-349

M. P. Experimental D-1

13 9 1911
8 x 10½

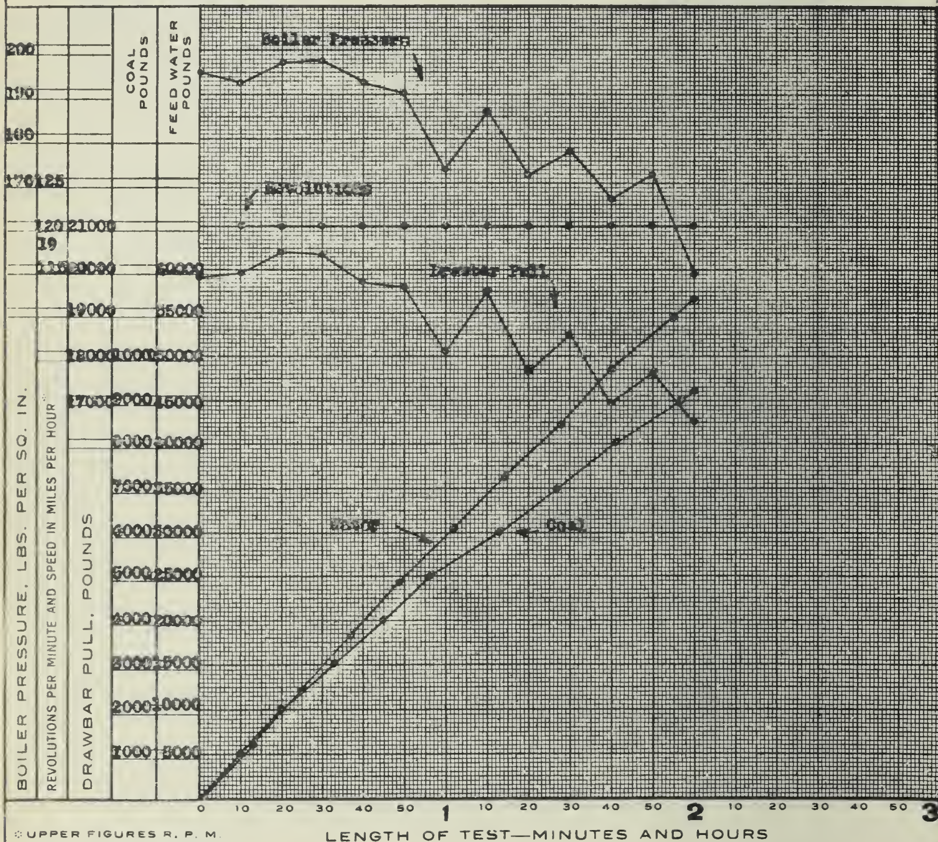
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-350 TEST DEPARTMENT Bulletin NO. 9

GRAPHICAL LOG OF LOCOMOTIVE TEST

Self Cleaning Front End ALTOONA, PA., 1-25-1910



∴ UPPER FIGURES R. P. M.
LOWER FIGURES APPROX.
SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 2-8-0
CLASS H6b
NUMBER 2860

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
19.2	120	40	Full	6.1

TEST NO. 1200,439

SHEET NO. P 350

M. P. Experimental D-1

12-4-1911
8 x 10½

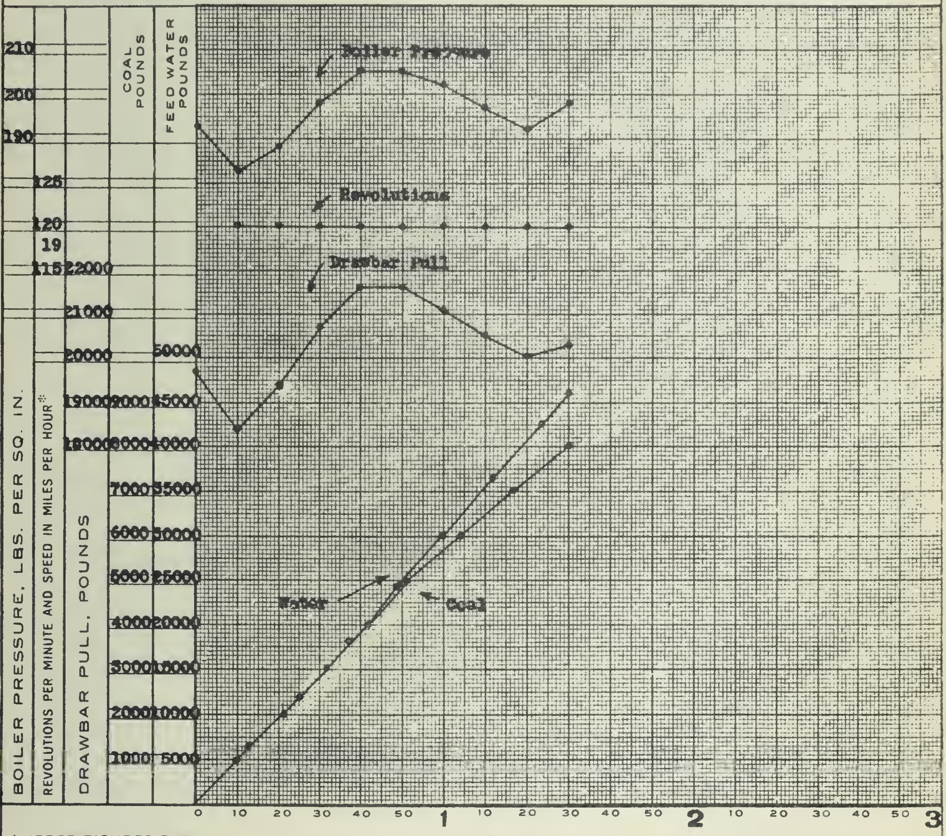
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. **P-351** TEST DEPARTMENT **Bulletin** NO. **9**

GRAPHICAL LOG OF LOCOMOTIVE TEST

Self Cleaning Front End ALTOONA, PA **1-10-1910**



*UPPER FIGURES R. P. M.
LOWER FIGURES APPROX.
SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE **2-8-0**
CLASS **H6b**
NUMBER **2860**

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
19.3	120	40	Full	5.7

TEST NO. **1200-430**

SHEET NO. **P-351**

M. P. Experimental D-1

12 9 1911
8 x 10½

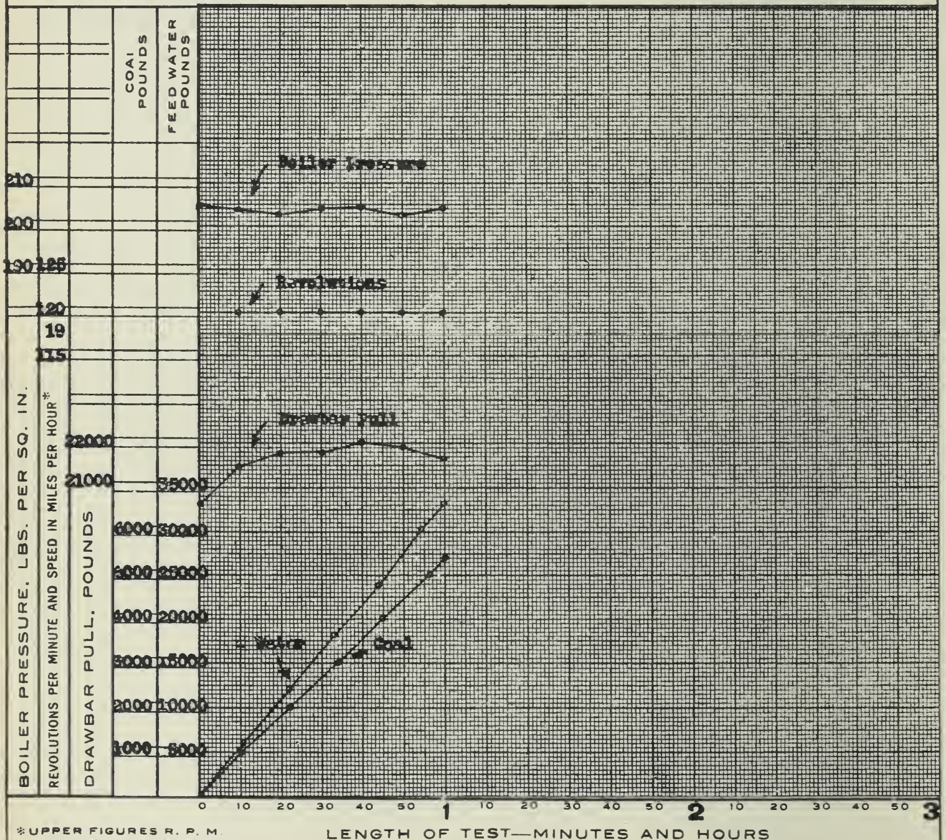
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-352 TEST DEPARTMENT Bulletin NO. 9

GRAPHICAL LOG OF LOCOMOTIVE TEST

Self Cleaning Front End ALTOONA, PA., 1-11-1910



*UPPER FIGURES R. P. M.
LOWER FIGURES APPROX.
SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 2-8-0
CLASS H6b
NUMBER 2860

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
19.3	120	45	Full	6.2

TEST NO. 1200.431

SHEET NO. P-352

PENNSYLVANIA RAILROAD COMPANY

LOCOMOTIVE TESTING PLANT

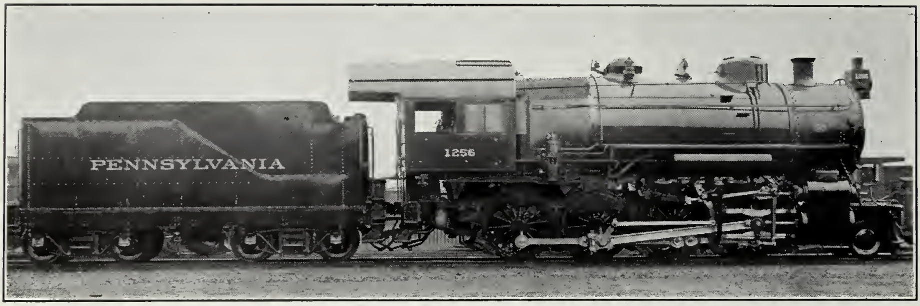
AT

ALTOONA, PENNA.

BULLETIN No. 10

TESTS OF A MODIFIED
CLASS H8SB LOCOMOTIVE

1914



CONSOLIDATION TYPE FREIGHT LOCOMOTIVE 1256.

Pennsylvania Railroad Company Class H8b (Saturated Steam). A locomotive of the same class as No. 1134, the one tested.

CONSOLIDATION TYPE FREIGHT LOCOMOTIVE 3473.

Pennsylvania Railroad Company Class H9s (Superheated Steam). The locomotive tested, No. 387, class H8sb, with 25-inch cylinders, is the same as the H9s class, except for a few minor details.

LOCOMOTIVE TESTING PLANT.

TESTS OF A CLASS H8sb CONSOLIDATION TYPE LOCOMOTIVE WITH CYLINDERS 25 INCHES IN DIAMETER.

Conclusions and recommendations on pages 107 to 109.

Index on page 147.

TESTS OF SIMPLE CONSOLIDATION TYPE LOCOMOTIVES WITH SATURATED AND SUPERHEATED STEAM, SHOWING THAT, BY THE USE OF HIGHLY SUPERHEATED STEAM IN ENLARGED CYLINDERS, THE H8B LOCOMOTIVE IS MADE MORE POWERFUL AND MORE ECONOMICAL IN FUEL AND WATER.

INTRODUCTION.

1. The Pennsylvania Railroad Company adopted early the consolidation locomotive for freight service, securing one of this type from the Baldwin Locomotive Works in 1873, and exhibiting one, built at Altoona, a class I, now known as class H1, at the Centennial Exhibition in Philadelphia in 1876.

2. The H1 locomotive carried 125 pounds boiler pressure and had cylinders 20 inches in diameter with a stroke 24 inches, a total weight in working order of 95,700 pounds and a tractive force of 19,200 pounds. In 1886, or ten years later, the class R, now known as the class H3, consolidation locomotive, an improved form, was built at Altoona; the steam pressure was 140 pounds with cylinders the same size as in the earlier design. The total weight in working order was 114,620 pounds, and the tractive force 21,504 pounds.

3. In common with many other large railroads, the Pennsylvania has adhered to the consolidation locomotive for the past 37 years, and it is yet the prevailing type for heavy freight service on this railroad.

4. The economies to be obtained by the operation of trains of large tonnage have been the cause of an unceasing call for more powerful locomotives, and following the H3 class of 1893 there were brought out the H6, H6a, and H6b, each with a tractive force of 39,688 pounds. Tests of an H6a locomotive were made at the Louisiana Purchase Exposition in 1904 and are recorded in Bulletin No. 4 and also in the report of the St. Louis tests of that year. In 1908 a further increase in size of freight locomotive was made in a design known as the H8 class, with a tractive force of 42,661 pounds. In 1912, with a view of increasing both the economy and power of the H8 locomotive, superheaters of the Schmidt type were installed in many of their boilers.

5. These locomotives have cylinders 24 inches in diameter with a 28-inch stroke. Their total weight in working order is 249,500 pounds, and they carry a working pressure of 205 pounds per square inch.

6. With the idea of providing a more suitable cylinder diameter for these consolidation locomotives, when using superheated steam, the cylinders on a single locomotive No. 387 were increased in diameter to 25 inches. The results obtained in road service after this change show an improvement in the performance of the locomotive, and this is further confirmed by the tests shown in this report. During the present year, many locomotives similar in design have been built. These new locomotives are known as the H9s class and are the heaviest locomotive of this type on the Pennsylvania Railroad at this date (January 1, 1914). Their total weight in working order is approximately 251,900 pounds and they have a tractive force of 46,290 pounds.

Description of Locomotive.

7. Locomotive 387 is of the simple consolidation type. It was built at Juniata Shops, by the Pennsylvania Railroad Company in June, 1909, and, at that time, was of the H8b design to use saturated steam. In December, 1912, this locomotive had a superheater applied and its cylinders increased from 24 to 25

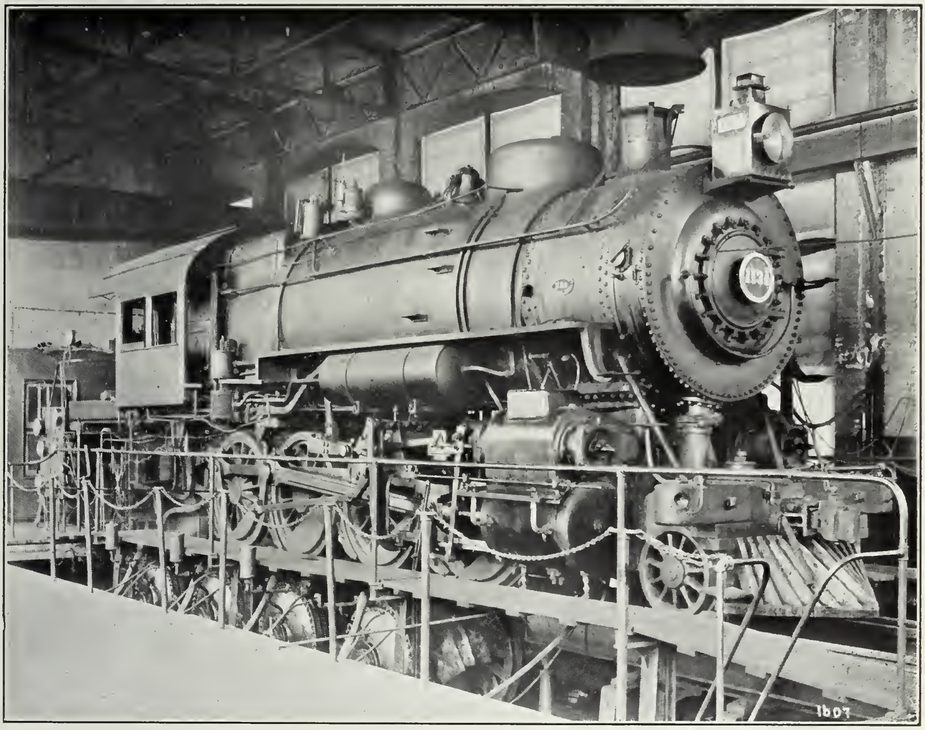


Fig. 1.

LOCOMOTIVE 1134, CLASS H8b (Saturated Steam).

Locomotive in position for test on Test Plant, Pennsylvania Railroad Company, Altoona, Pa.

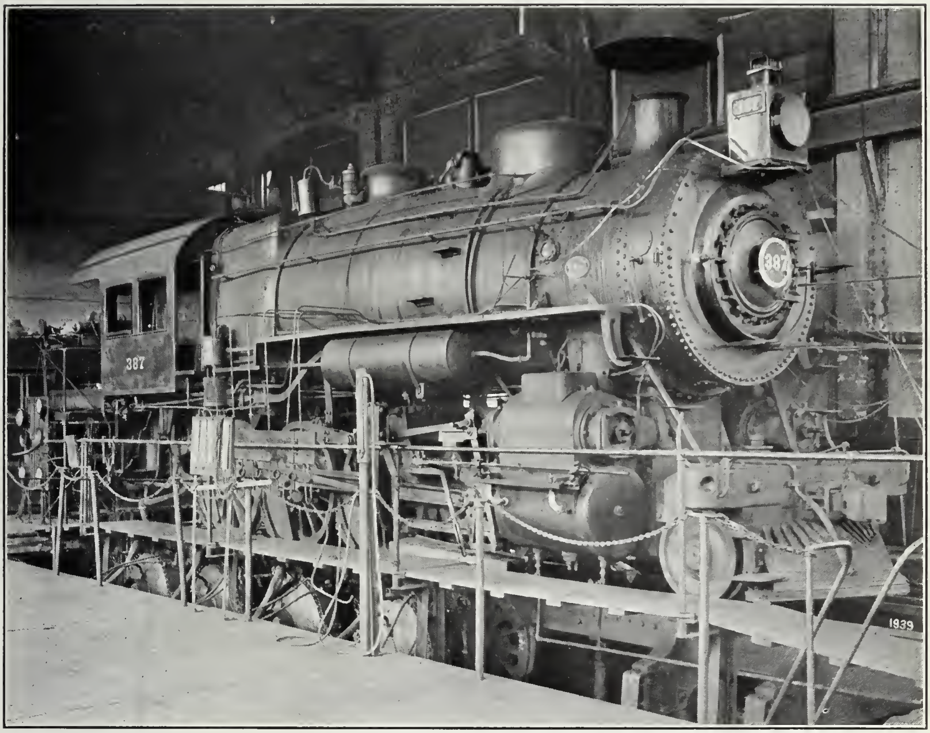


Fig. 2.
LOCOMOTIVE 387, CLASS H8sb, WITH 25-INCH CYLINDERS (Superheated Steam).
In position for test.

inches in diameter. Its classification was then changed to H8sb, although, because of the 25-inch cylinders, it thus became virtually the first locomotive of the H9s class. It was hand fired and had a brick arch.

8. The H9s locomotive is the outcome of an effort to obtain greater power and more economical performance by the use of superheated steam and enlarged cylinders. It has a heating surface (fireside) of 3536.6 square feet, while its predecessor, the H8b saturated steam locomotive, has 3403.2 square feet. This is an increase of 3.9 per cent. in the heating surface due to a rearrangement of tubes in the boiler, which was necessitated by the application of the superheater.

9. The general dimensions of this modified H8sb locomotive, No. 387, from measurements, are as follows:

Total weight in working order, pounds	249,500
Weight on drivers, working order, pounds	219,900
Cylinders (simple), inches	25 x 28
Diameter of drivers, inches	62
Heating surface in tubes (water side), square feet	2840.21
Firebox heating surface (fireside), including arch tubes, square feet	189.90
Heating surface of superheater (fireside)	808.98
Total heating surface (based on fireside of firebox and superheater and water side of tubes), including superheater and arch tubes, square feet	3839.09
Total heating surface (based on fireside), including superheater and arch tubes, square feet	3536.55
Grate area, square feet	55 34
Boiler pressure, pounds per square inch	205
Valves, type	14 in. Piston
Valve motion	Walschaerts
Firebox, type	Wide, Belpaire
Number of tubes	265
Number of flues (for superheater)	36
Outside diameter of tubes, inches	2
Outside diameter of flues, inches	$5\frac{3}{8}$
Length of tubes, inches	180.19

10. The maximum calculated tractive effort at starting is 46,290 pounds, with 80 per cent. of the boiler pressure available as mean effective pressure in the cylinders. This is equivalent to 282.2 pounds drawbar pull per pound of mean effective pressure. The ratio of the weight on drivers to the calculated tractive effort is 4.75.

General Arrangement.

11. The general arrangement of locomotive 387 is shown in Fig. 3 and cross-sections are shown in Fig. 4.

Boiler.

12. The boiler, Fig. 5, is of the Belpaire type with a wide grate. It contains 265 tubes, 2 inches outside diameter and 15 feet long, and 36 flues, $5\frac{3}{8}$ inches outside diameter, for superheater elements. The feed water from the injectors is conducted through a pipe $2\frac{3}{4}$ inches in diameter, extending from the back head of the boiler to a point 36 inches from the front tube sheet. Fig. 6 shows the front and back tube sheets.

13. The boiler has a sloping back head and throat sheet. It is equipped with a Schmidt type superheater and with a brick arch carried on three 3-inch water tubes.

Grates.

14. The grate arrangement is shown in Fig. 7. The grate rests on a cast-iron centre bearer 10 inches wide, running longitudinally with the firebox, and on frames attached to the sides of the firebox. The grate is separated by the centre grate bearer into two sections. Each section consists of a drop grate at both the front and back ends of the firebox, and separating these from the shaking grates are small fixed grates. The shaking grates are of the interlocking finger type and can be shaken in two separate sections.

15. The grates slope from the side of the firebox toward the centre grate bearer and the whole grate slopes from the rear toward the front end of the firebox.

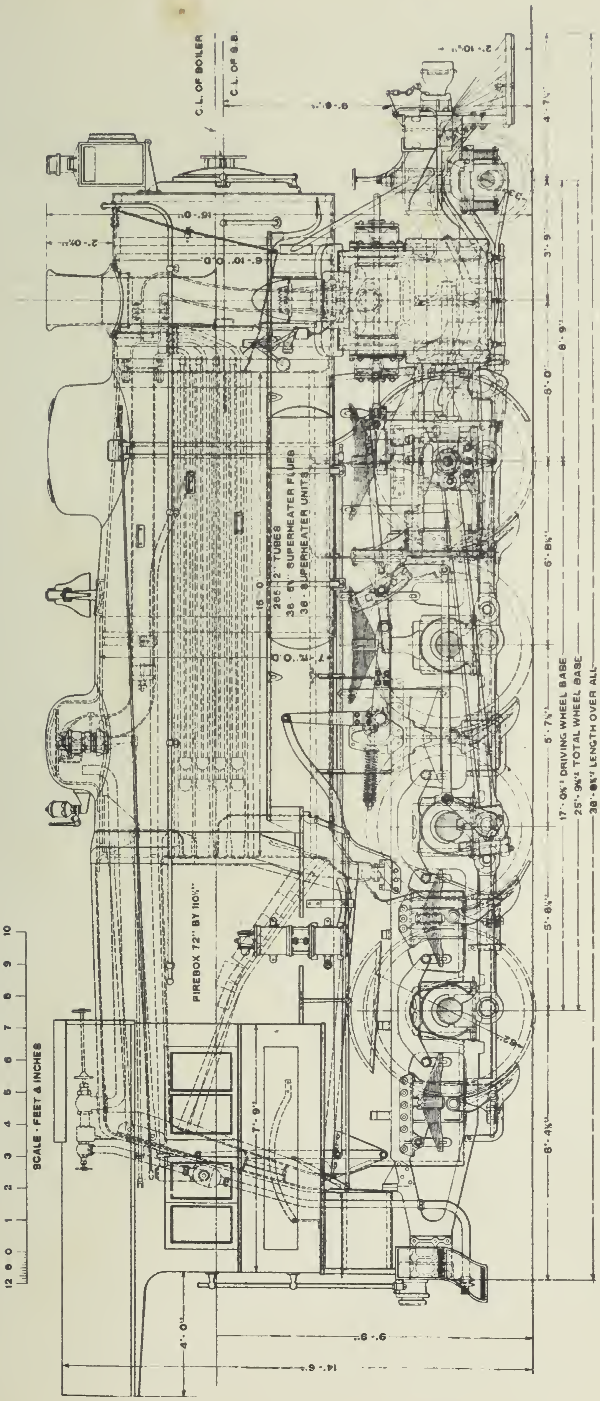


Fig. 3.
GENERAL ARRANGEMENT.
Class H8sb Locomotive 387.

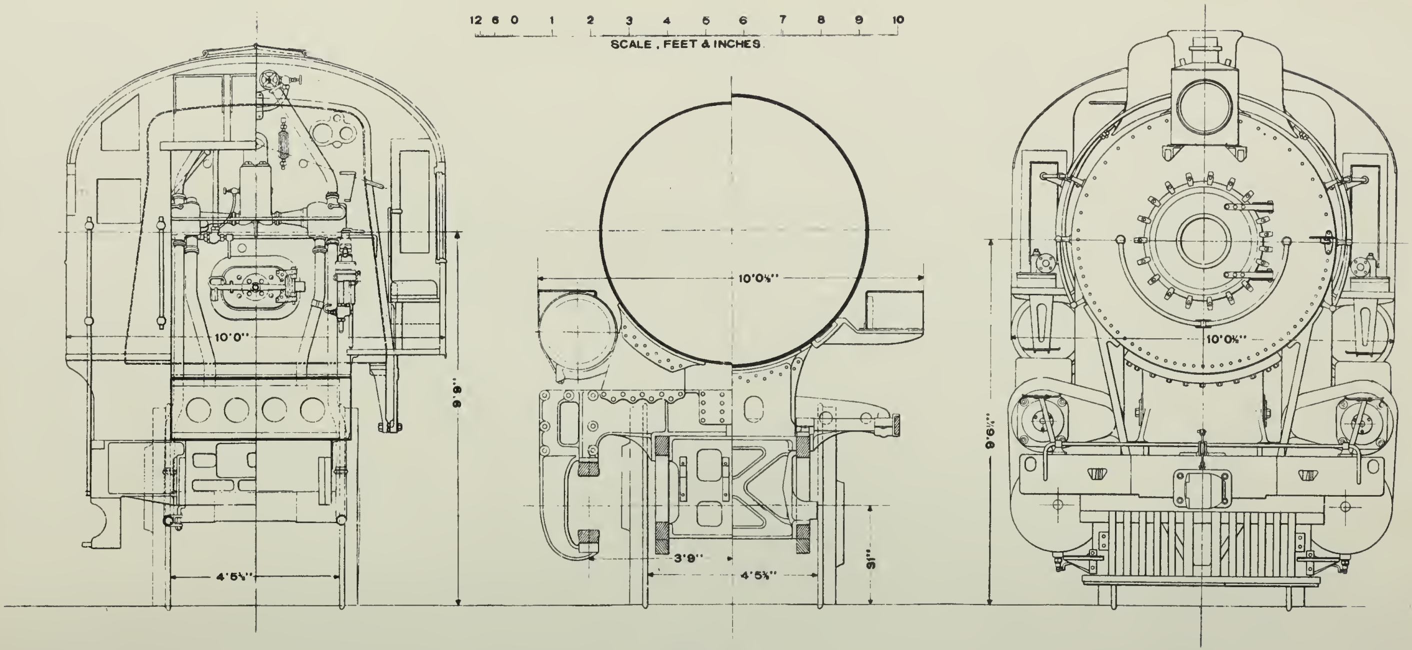


Fig. 4.
END ELEVATIONS AND CROSS SECTION.
Class H8sb Locomotive 387.

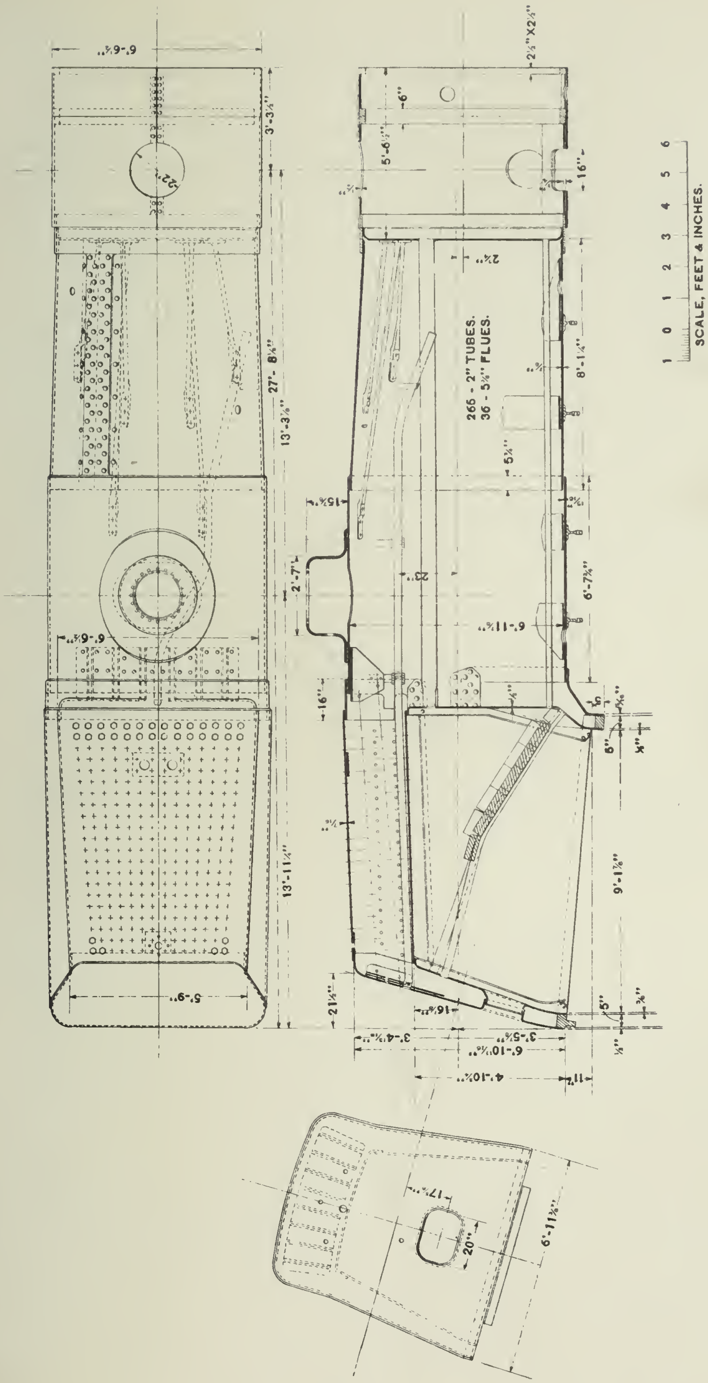


Fig. 5.
BOILER.
Class H8sb Locomotive 387.

16. The whole grate has an area of 55.34 square feet, of which the shaking portion is 25.76 square feet. The dimensions of the grate are 6 feet wide and 9 feet $2\frac{3}{8}$ inches long.

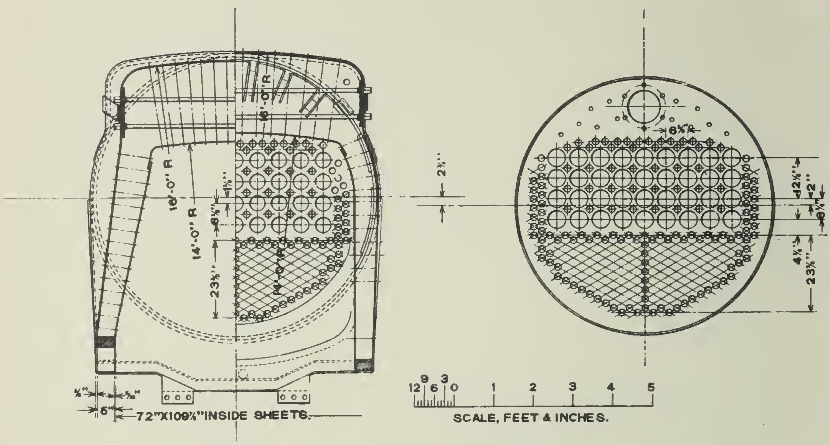


Fig. 6.
TUBE SHEETS.
Class H8sb Locomotive 387.

17. The ashpan is of the self-cleaning type and is operated from the side of the locomotive.

Smokebox.

18. The smokebox, designed to be self-cleaning, is shown in Fig. 8. It has an exhaust pipe $14\frac{1}{2}$ inches high. The exhaust nozzle (Fig. 9), rectangular in shape, is $4\frac{3}{4}$ x $6\frac{1}{2}$ inches, with an area of 30.88 square inches. A lift pipe, 17 inches inside diameter, extends from a point $17\frac{1}{8}$ inches above the exhaust nozzle to connect with the stack which tapers to an inside diameter of 19 inches at the top.

19. A sloping wire mesh netting extends from the top of the smokebox to the edge of the diaphragm plate which projects 18 inches beyond the vertical centre line of the exhaust pipe.

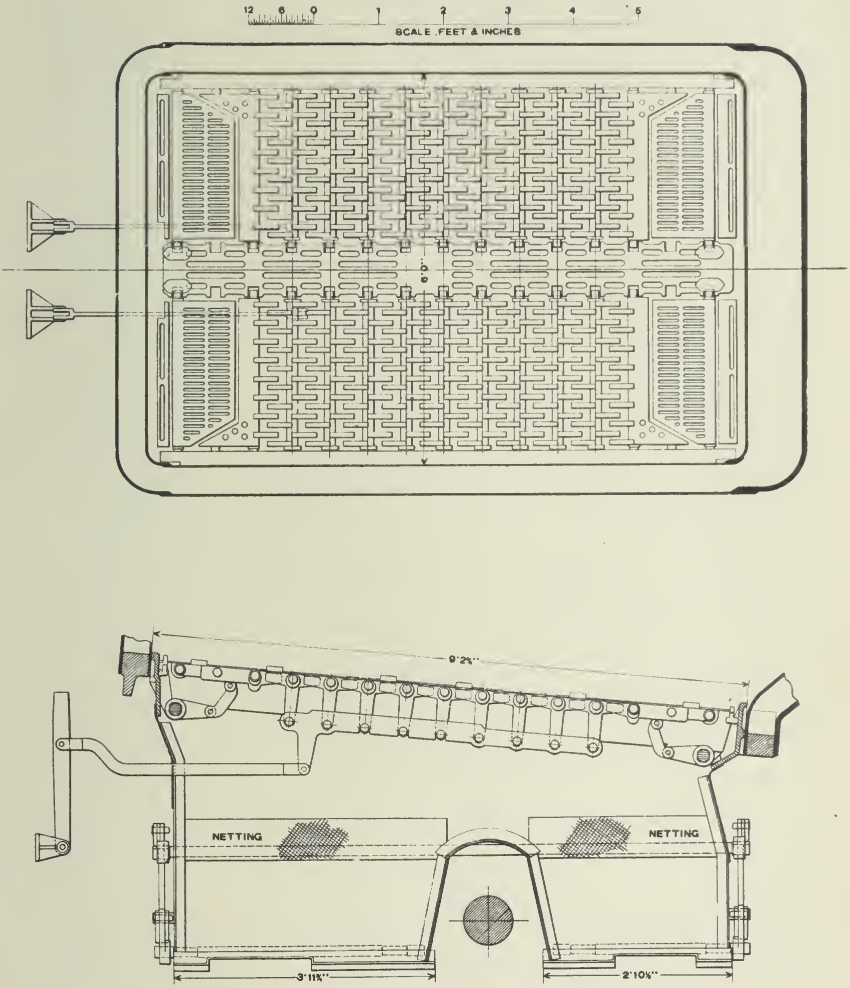


Fig. 7.
GRATE AND ASHPAN.
Class H8sb Locomotive 387.

20. In the arrangement used in the tests the diaphragm or table plate was horizontal, where it crossed the center line of the exhaust nozzle at a height of $15\frac{1}{2}$ inches above the bottom of the smokebox. This smokebox was found to be self-cleaning. A final arrangement of self-cleaning front end is described in Pars. 49 to 54.

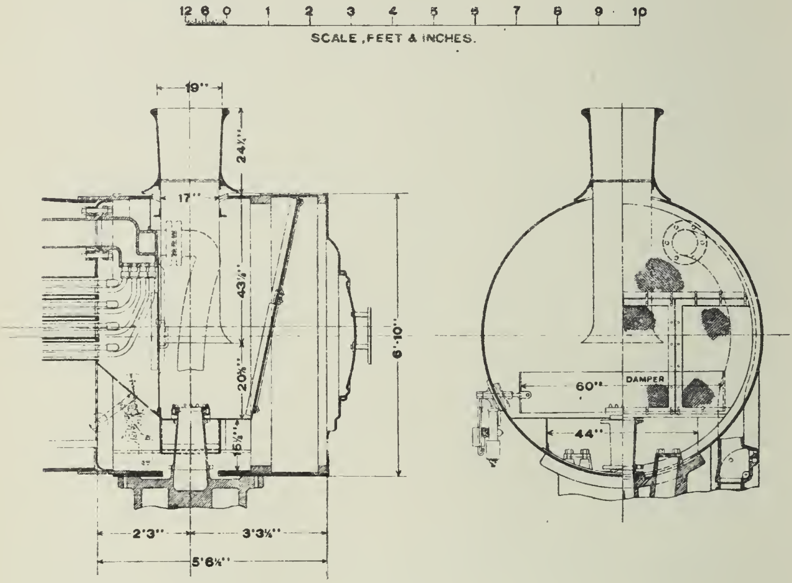


Fig. 8.
SMOKEBOX ARRANGEMENT.
Class H8sb Locomotive 387.

Superheater.

21. The superheater, Fig. 10, is of the Schmidt fire-tube type. It consists of 36 elements; each element has a double loop in one of the large fire tubes and extends to a point within two feet of the firebox end. The steam in flowing through the superheater passes twice through the hot gases in the flue.

22. The total heating surface of the superheater is 808.98 square feet, which is 22.8 per cent. of the total heating surface of the boiler.

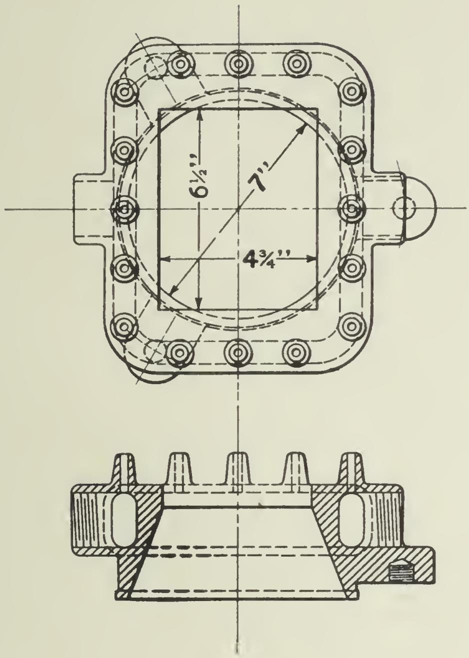


Fig. 9.
EXHAUST NOZZLE.
Class H8sb Locomotive 387.

Cylinders.

23. This locomotive 387 differs from the standard in one important particular; the diameter of its cylinders is 25 inches. The standard cylinders for this class of locomotive, when using saturated steam, have a diameter of 24 inches with a stroke of 28 inches. For the purpose of utilizing the full advantage of superheated steam, the cylinders applied to this locomotive were increased in diameter.

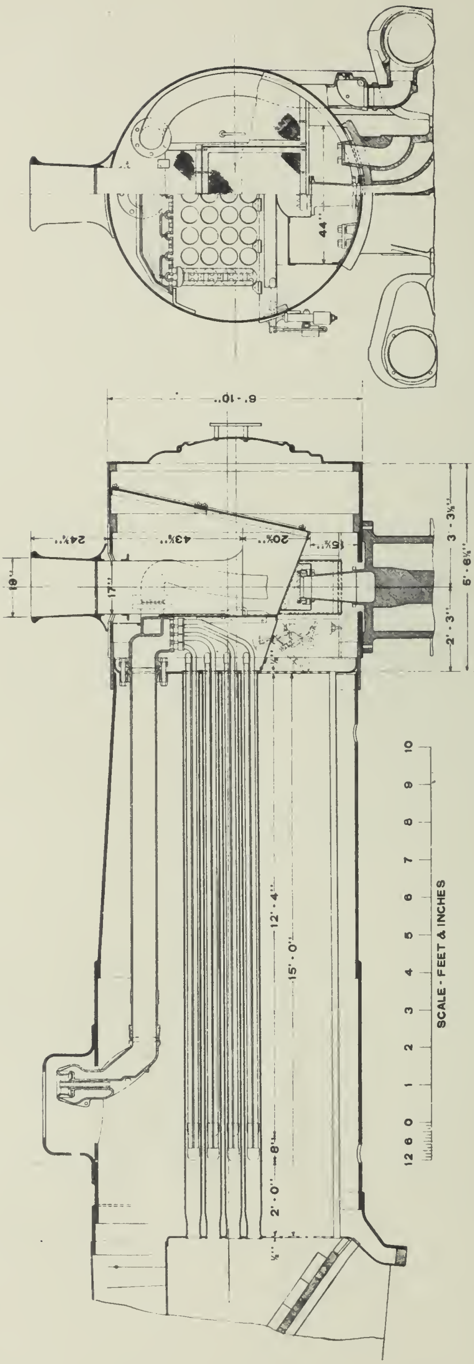


Fig. 10.
SUPERHEATER AND SMOKEBOX.
Class H8sb Locomotive 387.

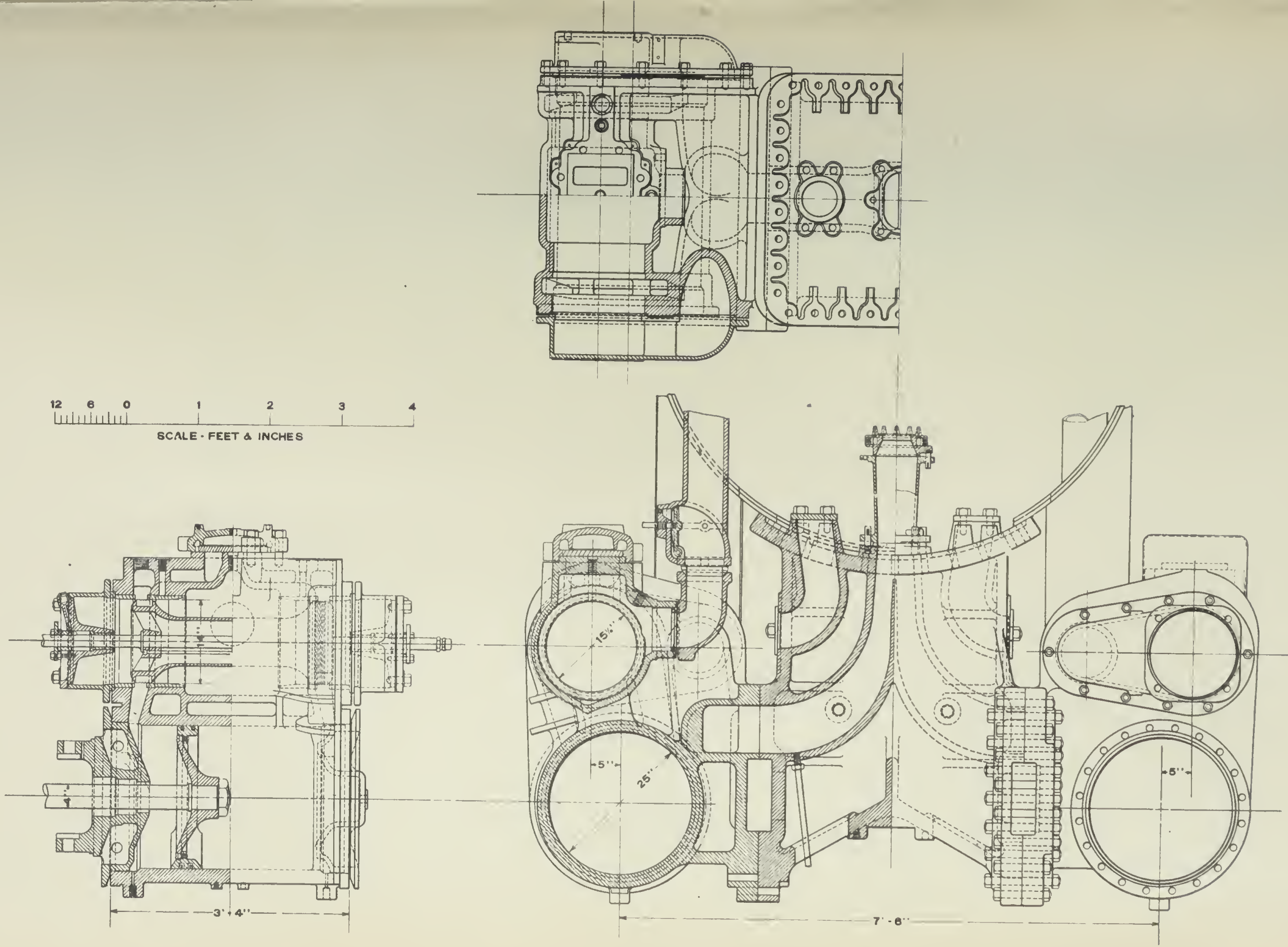


Fig. 11.
CYLINDER.
Class H8sb Locomotive 387.

24. The cylinders, Fig. 11, are made of cast iron. The saddle and each cylinder are cast separately. The steam passages are direct, but the exhaust passages have a number of turns. With the application of a superheater, new steam pipes are applied as shown and these extend through the sides of the smokebox and connect to the top of the steam chests, thus offering a direct passage from the superheater header to the valves. These outside steam pipes serve to prevent excessive expansion or contraction in the cylinder saddle which might occur with highly superheated steam conducted through it.

Piston Valves.

25. The piston valves, Fig. 12, are of the semi-plug type, 14 inches in diameter, made by the American Balance Valve

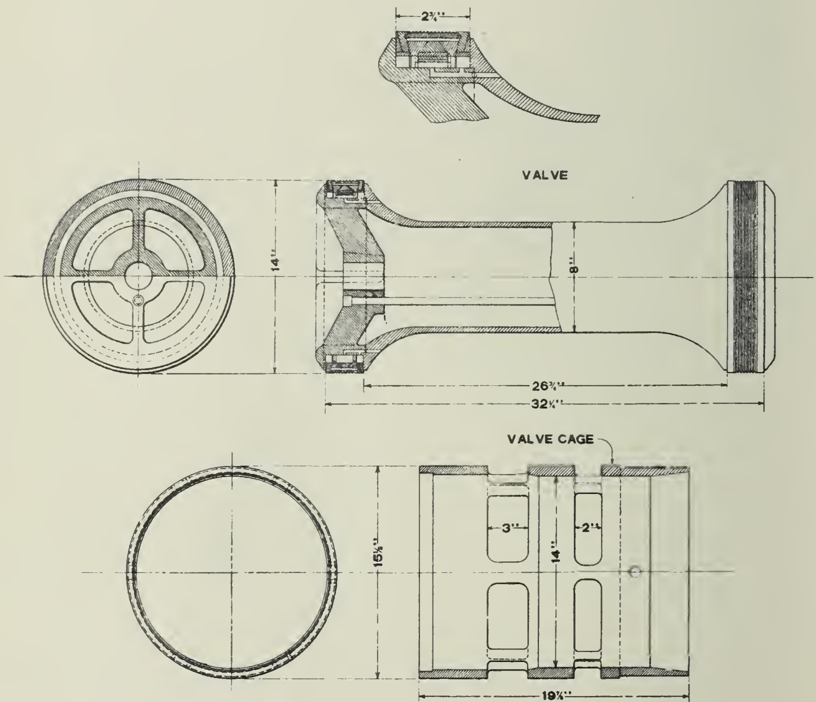


Fig. 12.
PISTON VALVE.
Class H8sb Locomotive 387.

Company. This size has been standard for locomotives of the H8, H8b and H8sb classes. The size adopted, however, for the H9s, of which the 387 was but a forerunner, is 12 inches in diameter. Tests relative to the proper size of valve will be the subject of Bulletin No. 23. The bearing face of the valve is formed by two narrow expanding rings connected by a thin wide ring with a number of "V" shaped grooves. (See Bulletin 7 for a more detailed description and tests.)

Tests.

26. There were 47 tests made with the H8sb locomotive 387. A number of these tests have been omitted, due to low steam pressure or the very short duration of the tests, making the data unreliable.

27. Thirty-nine tests of the 387 are presented in this bulletin, and all were made with a wide open throttle, and the speeds were from 7.2 to 30.5 miles per hour with a cut-off ranging from 20 to 88 per cent. These tests are shown in the following table, which indicates the number of tests run under each speed and cut-off.

Tests Made With H8sb Locomotive No. 387
Superheated Steam, 25-inch Cylinders.

Revolutions Per Minute R. P. M.	Miles Per Hour M. P. H.	Nominal Cut-off in Per Cent. of Stroke													
		20	25	30	35	40	45	50	55	58	63	68	75	86	88
40	7.19	1	....	1	....	....	....	....	....	....	....	....	1	....	1
60	10.83	2	....	1	1	....	....	....	....	....	....	1	1	1	....
80	14.44	1	....	1	....	2	....	....	1	1	1	....	....	....	....
100	17.97	....	3	....	....	2	1	1	1	....	....	....	....	....	....
120	21.56	1	....	1	....	1	....	2	....	....	....	....	....	....	....
140	25.16	....	1	....	1	1	....	....	....	....	....	....	....	....	....
160	28.75	....	....	1	1	1	....	....	....	....	....	....	....	....	....
170	30.50	1	....	....	1	....	....	....	....	....	....	....	....	....	....

In 1912, tests were made with class H8b saturated steam locomotive 1134 and the test results are shown in the tables on pages 121 to 131 and on many of the diagrams.

An outline of the test conditions is given in the following table.

Tests Made With H8b Locomotive No. 1134
Saturated Steam, 24-inch Cylinders.

Revolutions Per Minute R. P. M.	Miles Per Hour M. P. H.	Nominal Cut-off in Per Cent. of Stroke			
		20	27	35	42
60	11.0	2			
80	14.7		2	2	
100	18.3				2
120	22.0				2

Coal Used.

28. The fuel used during the tests was a bituminous coal mined by the Jamison Coal and Coke Company in Westmoreland County, Penna. It is a run of mine coal as used in freight service on this road.

29. Table VI, column 248, shows the heating value to range from 13,330 to 14,661 B. t. u. per pound.

30. As each car was being unloaded at the Test Plant samples were taken for analysis. The analysis of the coal shows results as follows:

Proximate Analysis.

Fixed Carbon, per cent.	58.02
Volatile matter, per cent.	31.59
Moisture, per cent.	1.20
Ash, per cent.	9.19
	100.00
Sulphur, separately determined, per cent.	1.44
B. t. u. per pound, dry	14,140
B. t. u. in combustible	15,590

Ultimate Analysis.

Carbon, per cent.	76.00
Hydrogen, per cent.	4.95
Nitrogen, per cent.	1.40
Sulphur, per cent.	1.79
Ash, per cent.	9.98
Oxygen by difference, per cent.	5.88
	100.00

BOILER PERFORMANCE.

Steam Pressure and Temperature.

31. The operation of the locomotive with regard to its steam pressures and temperatures is shown in Tables I and II. The steam pressures in Table I are for the boiler, dry pipe, the superheater header (saturated side), return bend (or the middle point of the superheater length), the branch pipe and the exhaust passage.

32. The boiler pressure, with but two exceptions, ranged between 198 and 206.0 pounds. At the return bend, where the steam has passed through one-half of a superheater element, the pressure shows a drop, ranging between 2.6 and 7.4 pounds. After the steam had passed through the superheater its pressure was observed at the branch pipe. The maximum drop in pressure at this point was 11.0 pounds or 5.6 per cent. of the boiler pressure (Test No. 3217). The pressure in the exhaust passage, observed by steam gage, ranged from 0 to a maximum of 7.7 pounds.

33. The steam temperatures, Table II, are shown for boiler, branch pipe, exhaust passage and the superheat in the exhaust passage. The superheat in the branch pipe ranged between 97.3 and 210.2 degrees Fahr., and in the exhaust passage from 3.6 and 81 degrees Fahr.

34. The temperature in the firebox and smokebox, together with the temperature of the steam in the branch pipe and the superheat in degrees Fahr. at the different rates of combustion, are graphically presented in Fig. 13. Thus the temperature in the firebox ranged between 1780 and 2510 degrees Fahr. and that in the smokebox between 448 and 673 degrees Fahr. The rate of firing is shown to range from 1000 to 7500 pounds of dry coal per hour.

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LOCOMOTIVE:
TYPE 2-8-0
CLASS H8sb No. 387

SHEET No. P-1149

Tests of a Class H8sb Locomotive.

PENNSYLVANIA RAILROAD COMPANY
PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

TEST DEPARTMENT

Bulletin No. 10

ALTOONA, PA. 1-7-1914

STEAM PRESSURES.

Test No.	Test Designation	Duration of Test Minutes	Steam Pressure by Gage In Boiler	Dry Pipe	Superheater Header Saturated Side	Return Bend	Branch Pipe	Exhaust Passage
			217				220	
3207	40-20-F	120	205.3	203.3	203.3	201.2	201.2	0.0
3210	40-30-F	120	205.3	205.3	202.0	202.0	202.0	0.0
3246	40-75-F	30	206.0	203.5	203.3	201.7	200.0	4.8
3247	40-88-F	15	206.0	204.7	204.0	201.9	200.7	6.3
3205	60-20-F	45	205.8	203.3	202.8	202.1	201.2	0.0
3206	60-20-F	105	205.9	203.0	202.1	202.1	201.7	0.0
3209	60-30-F	90	206.0	205.3	204.0	201.8	201.5	0.0
3227	60-35-F	90	206.0	204.4	203.2	201.3	201.2	1.6
3242	60-68-F	30	206.0	204.3	203.5	201.5	198.5	4.8
3245	60-75-F	30	203.3	202.0	201.3	199.0	194.7	6.7
3244	60-86-F	15	195.0	193.0	192.7	189.2	186.0	7.7
3201	80-20-F	120	205.8	203.5	203.5	202.5	202.4	0.0
3202	80-30-F	90	205.3	204.3	203.5	202.0	202.0	1.3
3203	80-40-F	30	206.0	204.8	204.0	203.4	201.5	2.0
3204	80-40-F	105	205.5	202.6	201.8	201.5	199.4	0.0
3238	80-55-F	30	206.0	204.0	203.8	202.4	200.0	4.0
3239	80-58-F	60	204.9	202.1	202.1	199.9	196.7	5.0
3241	80-63-F	60	204.7	203.0	203.0	200.7	195.9	6.9
3208	100-25-F	60	206.3	203.2	203.2	202.0	200.8	1.0
3211	100-25-F	30	205.8	205.5	203.8	202.2	201.0	1.0
3212	100-25-F	120	205.5	205.5	203.8	201.8	200.8	1.0
3213	100-40-F	30	203.3	203.3	202.0	198.9	197.3	3.3
3214	100-40-F	120	202.3	201.2	199.5	197.2	195.4	3.0
3215	100-45-F	120	204.5	202.8	201.5	198.5	196.2	4.1
3236	100-50-F	60	205.4	203.4	203.4	201.2	196.6	5.0
3237	100-55-F	60	203.4	201.4	201.4	198.4	194.6	5.1
3223	120-20-F	120	206.0	203.9	203.0	201.7	201.1	1.0
3221	120-30-F	120	205.9	205.2	203.7	201.2	199.8	2.8
3230	120-40-F	120	204.3	202.2	201.5	198.2	195.3	4.0
3216	120-50-F	60	186.1	185.3	184.1	180.6	176.3	5.9
3217	120-50-F	45	198.0	196.6	195.4	190.6	187.0	6.2
3225	140-25-F	90	205.6	203.9	202.5	200.2	199.4	2.0
3218	140-35-F	120	198.3	197.0	196.2	192.9	190.5	3.8
3220	140-40-F	60	204.9	203.7	202.7	199.2	196.0	5.1
3229	160-30-F	120	204.9	202.8	202.2	199.4	197.7	3.8
3222	160-35-F	60	203.3	201.3	200.7	197.3	194.7	4.9
3235	160-40-F	60	198.7	195.6	195.3	192.1	189.1	5.4
3228	170-20-F	120	205.8	204.5	202.9	201.5	200.3	2.0
3224	170-35-F	60	204.1	201.7	200.6	197.4	195.4	4.9

SHEET No. P-1149

Table I.

STEAM PRESSURE.

The pressure of the steam as it flows from the boiler to the exhaust nozzle is shown in this table. At the return bend, where the steam had passed through one-half of the superheater elements, there was a pressure drop ranging from 2.6 to 7.4 pounds. The maximum drop in pressure at the branch pipe was 11 pounds. In the exhaust passage the pressure ranged from 0 to 7.7 pounds.

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LOCOMOTIVE:
TYPE 2-8-0
CLASS H8sb No. 387

PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

TEST DEPARTMENT

Bulletin No. 10

SHEET NO. P-1150

Tests of a Class H8sb Locomotive.

ALTOONA, PA. 1-7-1914

STEAM TEMPERATURES.

Test No.	Test Designation	Duration of Test Minutes	Temperatures in			
			Boiler	Branch Pipe	Exhaust Passage	Superheat in Exhaust Passage
3207	40-20-F	120	389.7	485.5	220.0	8.1
3210	40-30-F	20	389.7	519.2	222.2	10.3
3246	40-75-F	30	390.0	558.5	282.0	56.8
3247	40-88-F	15	390.0	559.3	306.0	76.5
3205	60-20-F	45	389.8	489.3	218.7	6.8
3206	60-20-F	105	390.5	497.3	220.0	8.1
3209	60-30-F	90	390.1	518.4	228.0	16.5
3227	60-35-F	90	389.9	523.0	228.4	13.7
3242	60-68-F	30	390.0	560.0	279.5	54.3
3245	60-75-F	30	389.0	551.3	269.3	38.7
3244	60-86-F	15	390.0	564.0	314.0	81.0
3201	80-20-F	120	389.0	514.2	220.0	8.1
3202	80-30-F	90	385.7	521.2	218.0	3.6
3203	80-40-F	30	389.9	533.0	232.0	15.7
3204	80-40-F	105	389.7	539.5	230.2	18.3
3238	80-55-F	30	390.7	567.0	244.5	21.5
3239	80-58-F	60	389.5	580.9	280.9	55.1
3241	80-63-F	60	389.5	596.3	298.3	67.6
3208	100-25-F	60	390.1	545.0	225.7	12.0
3211	100-25-F	30	389.9	545.5	228.0	14.2
3212	100-25-F	120	389.7	542.2	227.5	14.5
3213	100-40-F	30	388.9	542.0	232.5	12.1
3214	100-40-F	120	388.6	562.1	231.0	10.5
3215	100-45-F	120	389.4	565.8	235.2	12.2
3236	100-50-F	60	389.7	586.9	252.0	26.8
3237	100-55-F	60	389.3	570.9	266.6	40.6
3223	120-20-F	120	389.9	514.8	222.0	9.0
3221	120-30-F	120	389.2	543.1	229.7	10.8
3230	120-40-F	120	383.6	574.2	235.8	13.4
3216	120-50-F	60	382.8	570.3	270.6	42.6
3217	120-50-F	45	386.8	578.8	278.8	50.2
3225	140-25-F	90	369.8	563.8	228.2	11.1
3218	140-35-F	120	386.9	546.5	231.8	9.8
3220	140-40-F	60	389.5	554.9	242.3	16.8
3229	160-30-F	120	389.5	568.8	231.7	9.7
3222	160-35-F	60	388.9	552.9	234.6	10.1
3235	160-40-F	60	383.0	577.1	252.0	25.5
3228	170-20-F	120	389.8	533.4	223.5	7.5
3224	170-35-F	60	389.3	570.9	236.6	10.9

SHEET NO. P-1150

Table II.

STEAM TEMPERATURES.

The steam temperatures correspond with the pressures shown in Table I. The boiler temperatures were obtained from the steam table; all other temperatures were observed.

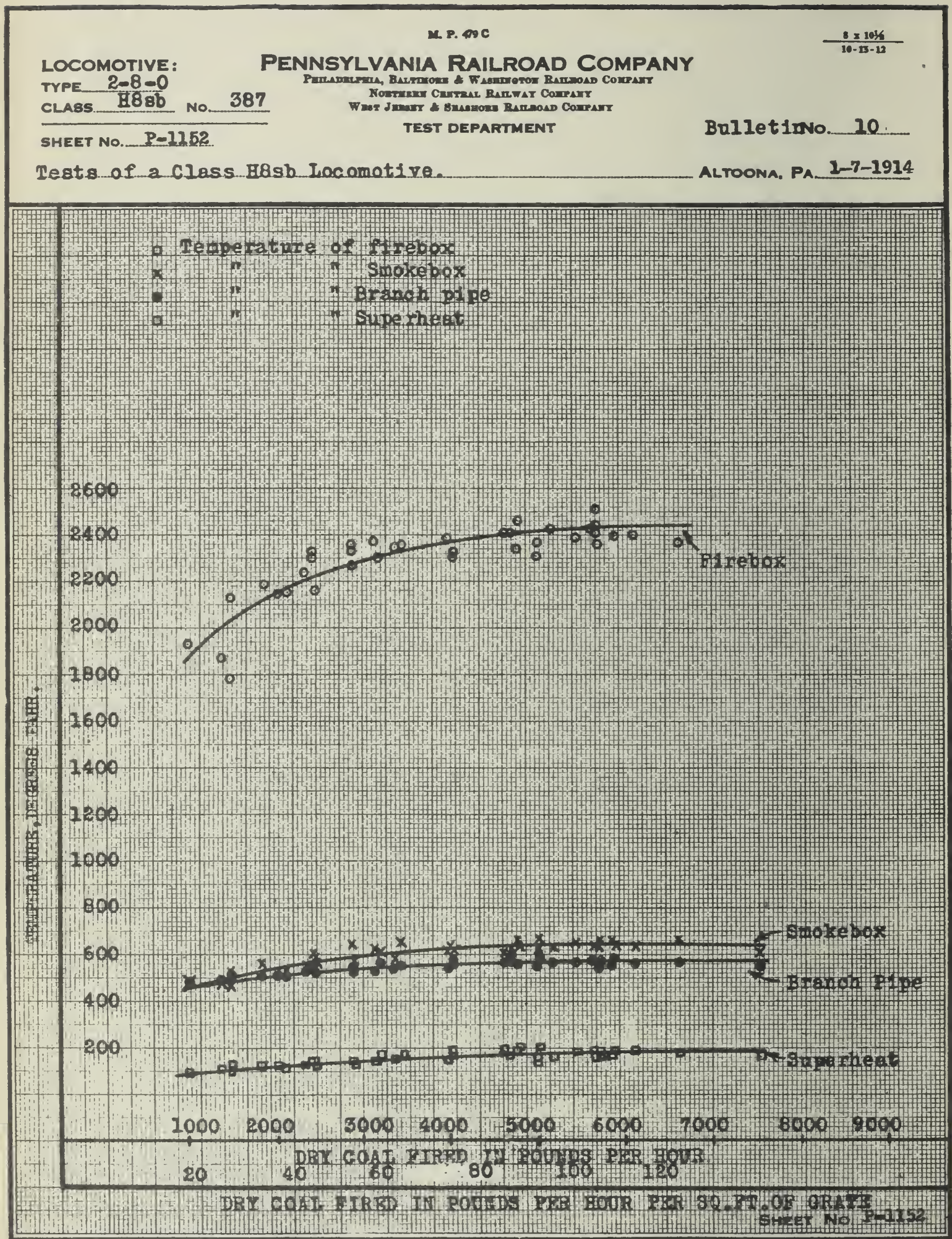

Fig. 13.

FIREBOX AND SMOKEBOX TEMPERATURE.

The temperatures of the steam in the branch pipe and the smokebox gases were practically constant after the combustion rate exceeded 100 pounds per square foot of grate per hour. Under the same conditions the temperature in the firebox increased but 20 degrees.

35. Meanwhile the temperature in the branch pipe ranged from 486 to 596 degrees Fahr., and the superheat between 97 and 210 degrees Fahr.

36. It is observed that, when the combustion rate exceeds 5500 pounds of coal fired per hour, which is equivalent to 100 pounds per square foot of grate, the degree of superheat, the temperature of the steam in the branch pipe and the temperature of the smokebox gases remain practically constant. The temperature in the firebox shows a tendency to decrease. This would indicate, above this rate of firing, the greater difficulty in obtaining perfect combustion.

Draft.

37. There is given in Table III the draft in inches of water, in front of diaphragm, back of diaphragm, in firebox and in ashpan, also the temperature in degrees Fahr. in firebox, smokebox and of the steam in the branch pipe. The last column gives the amount of coal fired per square foot of grate in pounds per hour during the several tests.

38. Fig. 14 presents graphically the relation between the rate of combustion in pounds of dry coal fired per square foot of grate per hour and the draft in inches of water.

39. The drafts in front and back of diaphragm are equal. This is an unusual result, indicating a very good front-end performance, or one having little or no loss in draft on account of the presence of the diaphragm. The draft in the smokebox increases from 0.9 to approximately 8 inches of water as the rate of combustion increases from 18 to 144.6 pounds of coal per square foot of grate per hour.

40. The draft in the firebox increases from 0.3 to 2.8 inches of water, while in the ashpan it ranges between 0.04 and 0.50 inches of water. The air openings into the ashpan have a total area of 7.52 square feet, or 13.6 per cent., of the grate area, and on account of the rather high vacuum in the ashpan these openings should be increased to about 8.5 square feet.

41. The distance intervening between the curves indicates that when 130 pounds of coal are fired per hour per square foot of grate the percentage of draft lost in the tubes or between the

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LOCOMOTIVE:
TYPE 2-8-0
CLASS H8sb No. 387

SHEET No. P-1151

PENNSYLVANIA RAILROAD COMPANY
PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY
TEST DEPARTMENT

Bulletin No. 10

Tests of a Class H8sb Locomotive. ALTOONA, PA. 1-7-1914

COMBUSTION, DRAFT AND TEMPERATURE.

Test No.	Test Designation	Duration of Test Mins.	Draft in Inches of Water: In front of Diaphragm	Draft: Back of Diaphragm	Draft: In Fire box	Draft: In Ash pan	Temperature Degrees F.: In Fire box	Temperature: In Smoke box	Temperature: Of Steam in Branch Pipe	Coal as fired per sq. ft. of Grate Pounds Per Hour
			222	223	224	225	212	207	210	
3207	40-20-F	120	0.9	0.9	0.4	0.04	1924	448	485.5	18.07
3206	60-20-F	105	1.1	1.0	0.3	0.17	1879	480	497.3	25.15
3205	60-20-F	75	1.3	1.1	0.4	0.13	1780	500	489.3	27.11
3210	40-30-F	120	1.5	1.3	0.3	0.08	2130	528	519.2	27.11
3201	80-20-F	120	1.7	1.5	0.7	0.05	2187	564	514.2	33.75
3209	60-30-F	90	2.0	1.8	0.7	0.10	2158	522	518.4	37.59
3223	120-20-F	120	2.0	1.9	0.8	0.07	2148	539	514.8	39.57
3227	60-35-F	90	2.3	2.1	1.0	0.08	2243	548	523.0	43.53
3202	80-30-F	90	2.4	2.1	0.9	0.09	2160	599	521.2	46.01
3212	100-25-F	120	2.3	2.1	0.9	0.11	2302	568	542.2	45.18
3228	170-20-F	120	2.9	2.7	1.5	0.13	2328	563	533.4	54.21
3208	100-25-F	60	2.4	2.3	0.9	0.10	2335	610	545.0	45.18
3211	100-25-F	30	2.6	2.3	1.1	0.18	2360	573	545.0	54.21
3204	80-40-F	105	3.2	2.8	0.8	0.15	2376	626	539.5	58.94
3225	140-25-F	90	3.2	3.2	1.2	0.12	2304	611	563.8	60.23
3203	80-40-F	30	3.0	2.8	0.9	0.13	2265	645	533.0	54.21
3221	120-30-F	120	3.7	3.5	1.7	0.22	2344	595	543.1	63.25
3246	40-75-F	30	5.4	5.5	1.7	0.10	2360	658	558.5	65.41
3214	100-40-F	120	4.0	3.7	1.6	0.18	2310	627	562.1	75.98
3213	100-40-F	30	4.5	4.2	2.0	0.25	2390	624	542.0	74.81
3229	160-30-F	120	4.6	4.4	2.1	0.22	2315	537	568.8	76.62
3218	140-35-F	120	5.5	5.3	2.8	0.48	2308	634	546.5	94.04
3215	100-45-F	120	5.1	4.8	2.1	0.27	2408	637	565.8	88.63
3230	120-40-F	120	5.1	4.9	2.2	0.23	2403	618	574.2	87.75
3247	40-88-F	15	6.2	6.4	2.1	0.12	2380	660	559.3	111.45
3238	80-55-F	30	5.4	5.2	2.3	0.10	2360	645	567.0	108.42
3222	160-35-F	60	5.9	5.6	2.6	0.28	2377	650	552.9	94.09
3224	170-35-F	60	5.8	5.6	2.4	0.31	2340	662	570.9	90.35
3242	60-68-F	30	6.0	6.1	2.2	0.11	2410	655	560.0	100.42
3236	100-50-F	60	5.8	5.6	2.2	0.15	2463	646	586.9	90.35
3220	140-40-F	60	5.9	5.7	2.3	0.31	2425	634	554.9	97.76
3245	60-75-F	30	7.8	7.9	2.8	0.10	--	670	551.3	144.56
3216	120-50-F	60	6.3	5.8	2.5	0.38	2423	640	570.3	106.44
3239	80-58-F	60	6.1	5.9	2.7	0.12	2395	637	580.9	111.54
3237	100-55-F	60	6.2	6.0	2.3	0.13	2510	651	570.9	108.42
3235	160-40-F	60	6.4	6.3	2.7	0.27	2387	651	577.1	103.04
3217	120-50-F	45	6.6	6.2	2.5	0.50	2405	646	578.8	115.65
3244	60-86-F	15	8.1	7.9	2.6	0.17	2370	673	564.0	126.63
3241	80-63-F	60	6.7	6.4	2.2	0.17	-	669	596.3	95.45

SHEET No. P-1151

Table III.

COMBUSTION, DRAFT AND TEMPERATURE.

The tests are arranged here according to the increase in equivalent evaporation. The vacuum in the ashpan is higher than usual, and the draft in the firebox does not exceed 2.8 inches of water.

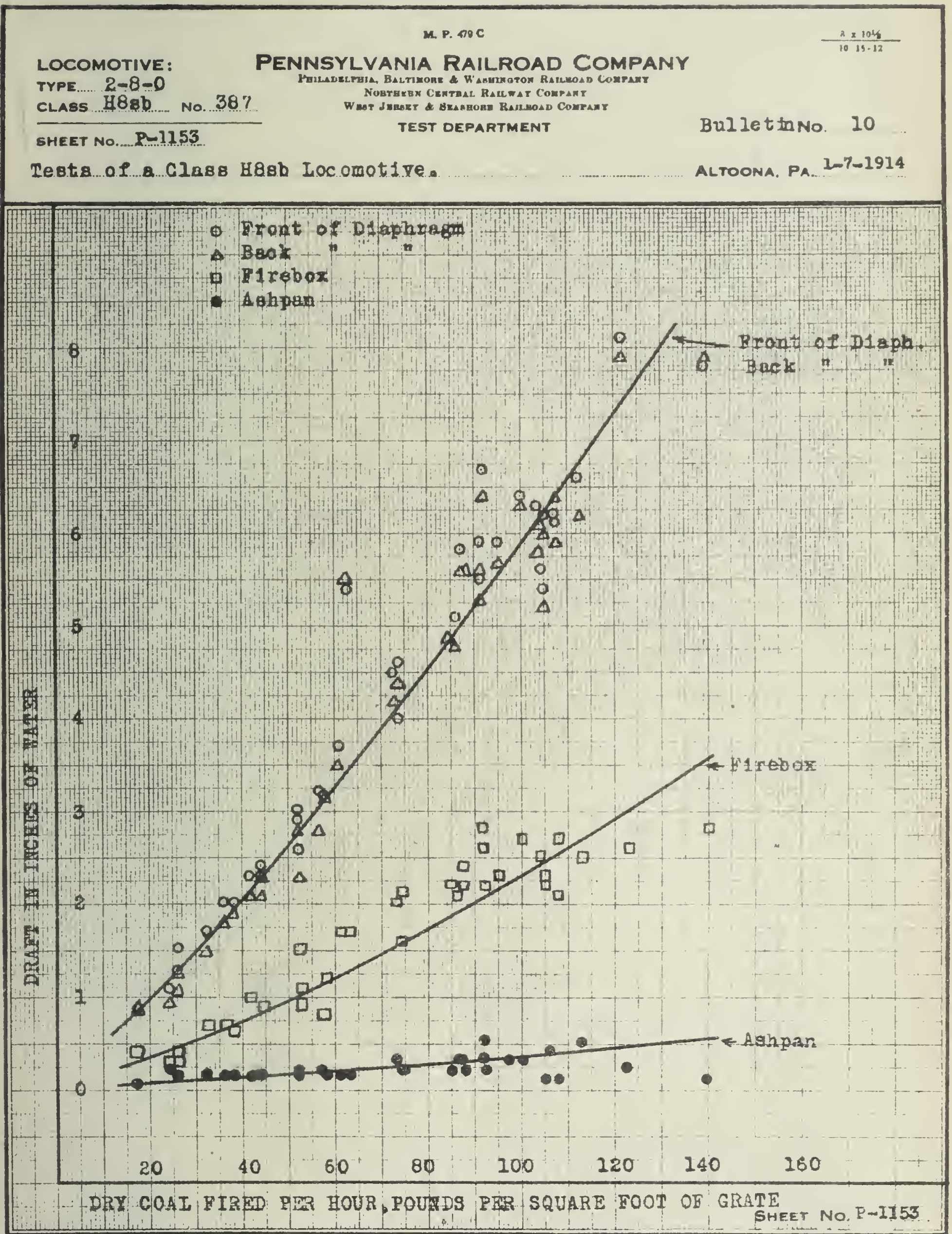

Fig. 14.

DRAFT AND RATE OF COAL BURNING.

At the front and back of diaphragm the drafts are equal. This is an unusual result, indicating a very good front end performance, as there was little or no loss in draft due to the presence of the diaphragm.

back of diaphragm and the firebox was 59 per cent., and that due to the coal and grate or between firebox and ashpan was 34 per cent.

Rate of Combustion and Horse-power.

42. The relation between the combustion rate in pounds of dry coal fired per hour per square foot of grate and the power developed is illustrated in Fig. 15. The curve for horse-power indicates that as the rate of firing increases the dynamometer horse-power approaches a point beyond which an increase in the firing rate would produce no more power, and it further shows that as the rate of combustion is increased the efficiency of the boiler drops from 81 to 37 per cent.

Smokebox Gases.

43. The analysis of the smokebox gases in per cent. of oxygen, carbon monoxide, carbon dioxide and nitrogen, together with the calorific value of the dry coal in B.t.u. per pound, are shown in Table VI. The heat in the coal which is lost by the presence of CO in the gases, the temperature of the smokebox in degrees Fahr. and the smoke in percentage according to the Ringelmann Scale are also known.

44. While the volume of carbon monoxide in the smokebox gases is apparently small, ranging from 0.0 to 2.6 per cent., it will be seen that in test 3238, only 2.3 per cent. of CO means a fuel waste of 9.84 per cent. The smoke ranged from 6 to 44 per cent. The locomotive was hand-fired, and to this fact, and to the presence of a brick arch in the firebox we may attribute this low percentage of smoke.

45. A gradual increase in the density of the smoke occurs as the rate of combustion is increased (see Fig. 16). The carbon monoxide likewise gradually increases until a rate of combustion approximating 5000 pounds of coal per hour is reached. Thereafter it increases with great rapidity. This indicates an insufficient air supply at the higher rates of combustion, further mention of which is made in Pars. 103 to 105 of this Bulletin.

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LOCOMOTIVE:
TYPE 2-8-0
CLASS H8sb No. 387

PENNSYLVANIA RAILROAD COMPANY
PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY
TEST DEPARTMENT

Bulletin No. 10

SHEET NO. P-1154
Tests of a Class H8sb Locomotive.

ALTOONA, PA. 1-7-1914

COMBUSTION, GENERAL CONDITIONS

Test No.	Test Designation	Duration of Test Mins.	Average Pressure in lbs. per sq. in.		Temperature Degrees Fahr.		Dry Coal Fired per Hour lb. per sq. ft. of Grate	Total water Evap. lbs. Per hour per sq. ft. of heating surface	Ratio Column 339 to 342
			Boiler Pressure	Atmospheric Pressure	Testing Plant	Feed Water			
			217	221	208	211	339	342	
3207	40-20-F	120	205.3	14.24	64	50.4	17.67	2.63	6.72
3206	60-20-F	105	205.9	14.24	50	45.7	24.59	3.41	7.21
3205	60-20-F	75	205.8	14.04	55	43.5	26.51	3.59	7.38
3210	40-30-F	120	205.3	14.30	52	49.3	26.51	3.66	7.24
3201	80-20-F	120	205.8	14.13	54	44.0	33.0	4.1	8.05
3209	60-30-F	90	206.0	14.38	56	51.6	36.74	4.65	7.84
3223	120-20-F	120	206.0	13.98	56	50.4	38.76	5.05	7.68
3227	60-35-F	90	206.0	13.90	59	55.9	42.39	5.35	7.92
3202	80-30-F	90	205.3	14.11	59	44.7	44.98	5.57	8.08
3212	100-25-F	120	205.5	14.08	61	46.4	44.16	5.65	7.81
3228	170-20-F	120	205.8	13.94	58	47.7	52.80	5.69	9.28
3208	100-25-F	60	206.3	14.20	62	46.5	44.16	5.85	7.55
3211	100-25-F	30	205.8	14.23	64	53.0	52.98	5.91	8.96
3204	80-40-F	105	205.5	13.99	58	44.0	57.63	6.64	8.68
3225	140-25-F	90	205.6	14.26	60	48.0	58.67	6.72	8.73
3203	80-40-F	30	206.0	14.06	61	43.0	52.98	6.83	7.76
3221	120-30-F	120	205.9	14.05	65	50.1	61.96	6.98	8.88
3246	40-75-F	30	206.0	14.27	58	48.0	63.46	7.40	8.58
3214	100-40-F	120	202.3	14.35	56	47.8	74.43	7.41	10.04
3213	100-40-F	30	203.3	14.04	67	47.0	73.15	7.59	9.64
3229	160-30-F	120	204.9	14.05	54	48.8	74.63	7.85	9.51
3218	140-35-F	120	198.3	14.09	69	47.8	92.12	8.04	11.45
3215	100-45-F	120	204.5	14.13	60	49.7	86.83	8.06	10.77
3230	120-40-F	120	204.3	14.04	58	50.5	85.47	8.24	10.37
3247	40-88-F	15	206.0	14.26	57	48.0	108.13	8.38	12.90
3238	80-55-F	30	206.0	14.21	59	50.7	105.60	8.43	12.53
3222	160-35-F	60	203.3	13.87	63	51.8	92.18	8.52	10.82
3224	170-35-F	60	204.1	14.28	55	50.0	88.00	8.68	10.14
3242	60-68-F	30	206.0	14.26	63	47.3	105.17	8.70	12.09
3236	100-50-F	60	205.4	14.04	74	50.0	88.49	8.72	10.15
3220	140-40-F	60	204.9	14.04	65	50.0	95.77	8.93	10.72
3245	60-75-F	30	203.3	14.27	54	48.3	140.22	8.97	15.63
3216	120-50-F	60	186.1	14.14	70	47.8	104.26	8.91	11.70
3239	80-58-F	60	204.9	14.20	55	48.0	108.69	8.90	12.21
3237	100-55-F	60	203.4	14.19	58	48.7	103.58	9.17	11.51
3235	160-40-F	60	198.7	14.07	70	52.2	100.92	9.20	10.97
3217	120-50-F	45	198.0	14.04	67	49.2	113.28	9.30	12.18
3244	60-86-F	15	195.0	14.23	66	48.0	122.80	9.51	12.91
3241	80-63-F	60	204.7	14.22	66	48.2	92.95	9.57	9.71

SHEET NO. P-1154

Table IV.

COMBUSTION, GENERAL CONDITIONS.

The arrangement of this table is according to the increase in evaporation. The dry coal fired per hour per square foot of grate ranged between 17.67 and 140.22 pounds per hour. The water evaporated per square foot of heating surface per hour increased from 2.63 to 9.57 pounds.

M. P. 479—A

8 x 10½
331 4-29-12

LOCOMOTIVE:
TYPE 2-8-0
CLASS H8sb No. 387

PENNSYLVANIA RAILROAD COMPANY
PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY
TEST DEPARTMENT

Bulletin No. 10

SHEET No. P-1155

Tests of a Class H8sb Locomotive. ALTOONA, PA., 1-4-1914

RATE OF COMBUSTION AND HEAT TRANSFER

Test No.	Test Designation	Duration of Test Mins.	Total Dry Coal Fired	Dry Coal Fired per Hour	Rate of Combustion		Heat Transfered across Water Heating Surface B.t.u. Per Minute	Heat Transfered across superheating Surface B.t.u. Per Minute
					Dry Coal Fired Per sq.ft.of Grate, pounds per hour	Dry Coal per sq.ft.of Heat.Surface lbs.per hour		
			235	338	339			
3207	40-20-F	120	1955	978	17.67	0.277	183214	8781
3206	60-20-F	105	2382	1361	24.59	0.385	238153	12675
3205	60-20-F	75	1100	1467	26.51	0.415	251283	10395
3210	40-30-F	120	2933	1467	26.51	0.415	255109	15878
3201	80-20-F	120	3652	1826	33.00	0.516	288334	16944
3209	60-30-F	90	3050	2033	36.74	0.575	323178	20170
3223	120-20-F	120	4290	2145	38.76	0.606	352014	20850
3227	60-35-F	90	3519	2346	42.39	0.663	370954	24036
3202	80-30-F	90	3733	2489	44.98	0.702	389966	24882
3212	100-25-F	120	4888	2444	44.16	0.691	394623	28537
3228	170-20-F	120	5843	2922	52.80	0.826	397192	27489
3208	100-25-F	60	2444	2444	44.16	0.691	408386	29926
3211	100-25-F	30	1466	2932	52.98	0.829	410223	30420
3204	80-40-F	105	5580	3189	57.63	0.902	464447	33298
3225	140-25-F	90	4870	3247	58.67	0.918	468796	38493
3203	80-40-F	30	1466	2932	52.98	0.829	478169	32886
3221	120-30-F	120	6857	3429	61.96	0.969	485900	36867
3246	40-75-F	30	1756	3512	63.46	0.993	516098	38027
3214	100-40-F	120	8237	4119	74.43	1.162	516819	46224
3213	100-40-F	30	2024	4048	73.15	1.144	528848	38723
3229	160-30-F	120	8259	4130	74.63	1.168	546948	46224
3218	140-35-F	120	10195	5098	92.12	1.441	560551	42749
3215	100-45-F	120	9610	4805	86.83	1.358	560944	46841
3230	120-40-F	120	9459	4730	85.47	1.337	573320	50004
3247	40-88-F	15	1496	5984	108.13	1.689	584348	44061
3238	80-55-F	30	2922	5844	105.60	1.652	586462	48112
3222	160-35-F	60	5101	5101	92.18	1.442	592018	46497
3224	170-35-F	60	4870	4870	88.00	1.377	604560	51932
3242	60-68-F	30	2910	5820	105.17	1.645	607229	46809
3236	100-50-F	60	4897	4897	88.49	1.384	608243	56038
3220	140-40-F	60	5300	5300	95.77	1.498	621938	49662
3245	60-75-F	30	3880	7760	140.22	2.193	625350	48337
3216	120-50-F	60	5770	5770	104.26	1.631	620756	54466
3239	80-58-F	60	6015	6015	108.69	1.700	620798	55342
3237	100-55-F	60	5843	5843	105.68	1.652	638965	54779
3235	160-40-F	60	5585	5585	100.92	1.579	638543	57475
3217	120-50-F	45	4702	6269	113.28	1.772	648125	58352
3244	60-86-F	15	1699	6796	122.80	1.921	663216	55780
3241	80-63-F	60	5144	5144	92.95	1.454	667237	64143

SHEET No. P-1155

Table V.

RATE OF COMBUSTION AND HEAT TRANSFER.

A comparison of the heat transfer across the water heating and across the superheating surfaces shows that the heat absorbed by the superheater was less than 10 per cent. of that absorbed by the water heating surface.

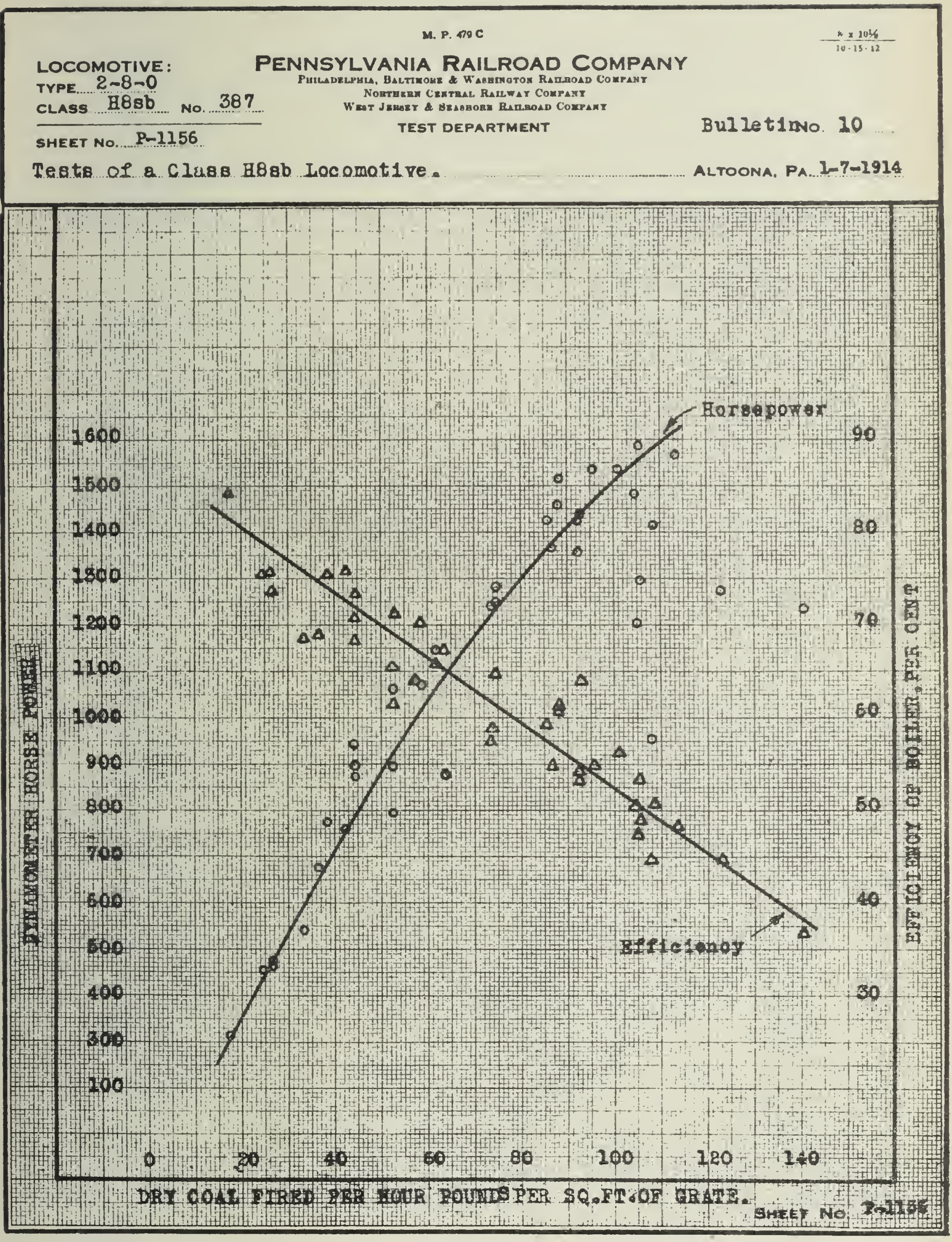

Fig. 15.

COMBUSTION RATE WITH RESULTING DYNAMOMETER HORSE-POWER AND EFFICIENCY.

The horse-power curve approaches a point at which the increase in the rate of firing has no effect toward increasing the dynamometer horse-power. The efficiency decreases with the increase in power and rate of firing.

Rate of Combustion.

46. The general conditions relating to the combustion rate for this locomotive are given in Table IV. The boiler pressure (column 217) was well maintained throughout the tests. The dry coal fired per hour per square foot of grate ranged between 17.67 and 140.22 pounds per hour (column 339). The total water evaporated per hour per square foot of heating surface increased with the rate of combustion from 2.63 to 9.57 pounds.

47. In Table V are given the total dry coal fired in pounds, the dry coal fired per hour in pounds, dry coal fired per square foot grate in pounds per hour, and per square foot of heating surface per hour, the heat transferred across the water heating surface in B.t.u. per minute and likewise across the superheating surface.

48. The heat transferred across the water heating surface ranged from 183,214 to 667,237 B.t.u. per minute, and that across the superheater heating surface from 8781 to 64,143 B.t.u. per minute. The heat absorbed by the superheater is thus less than ten per cent. of that absorbed by the water heating surface.

Stack and Nozzle.

49. This locomotive was equipped with a rectangular nozzle with an opening $4\frac{3}{4}$ by $6\frac{1}{2}$ inches (see Fig. 9), a self-cleaning front end with a lift pipe 17 inches in diameter and a stack tapering to 19 inches in diameter at the top (Fig. 8).

50. Dynamic pressure observations of the gases leaving the stack were taken, as explained in Bulletin 19, Par. 90 to 96, and are presented here in Fig. 17.

51. The maximum evaporation obtained was 39,955 pounds per hour. The pressures as plotted on the diagrams representing the stack from left to right and front to back indicate a uniform distribution of the gases across the stack opening in almost every instance. The only variation occurs in the plane from left to right at the maximum rate of evaporation when the pressures tend toward a peak at the centre, but are by no means excessive.

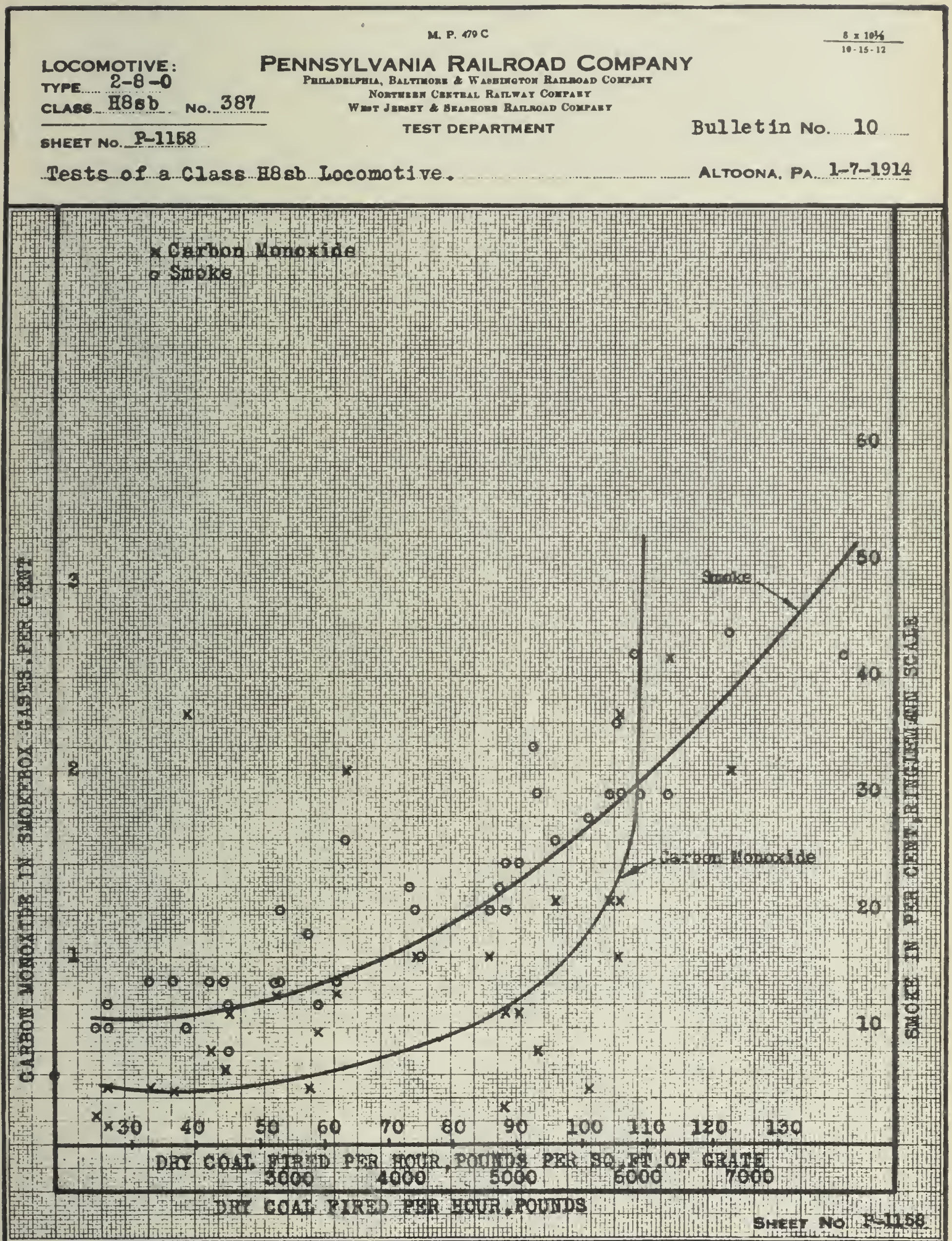

Fig. 16.

CARBON MONOXIDE.

The carbon monoxide and smoke increased rapidly after a rate of combustion of 5000 pounds of coal per hour was exceeded, indicating an insufficient air supply.

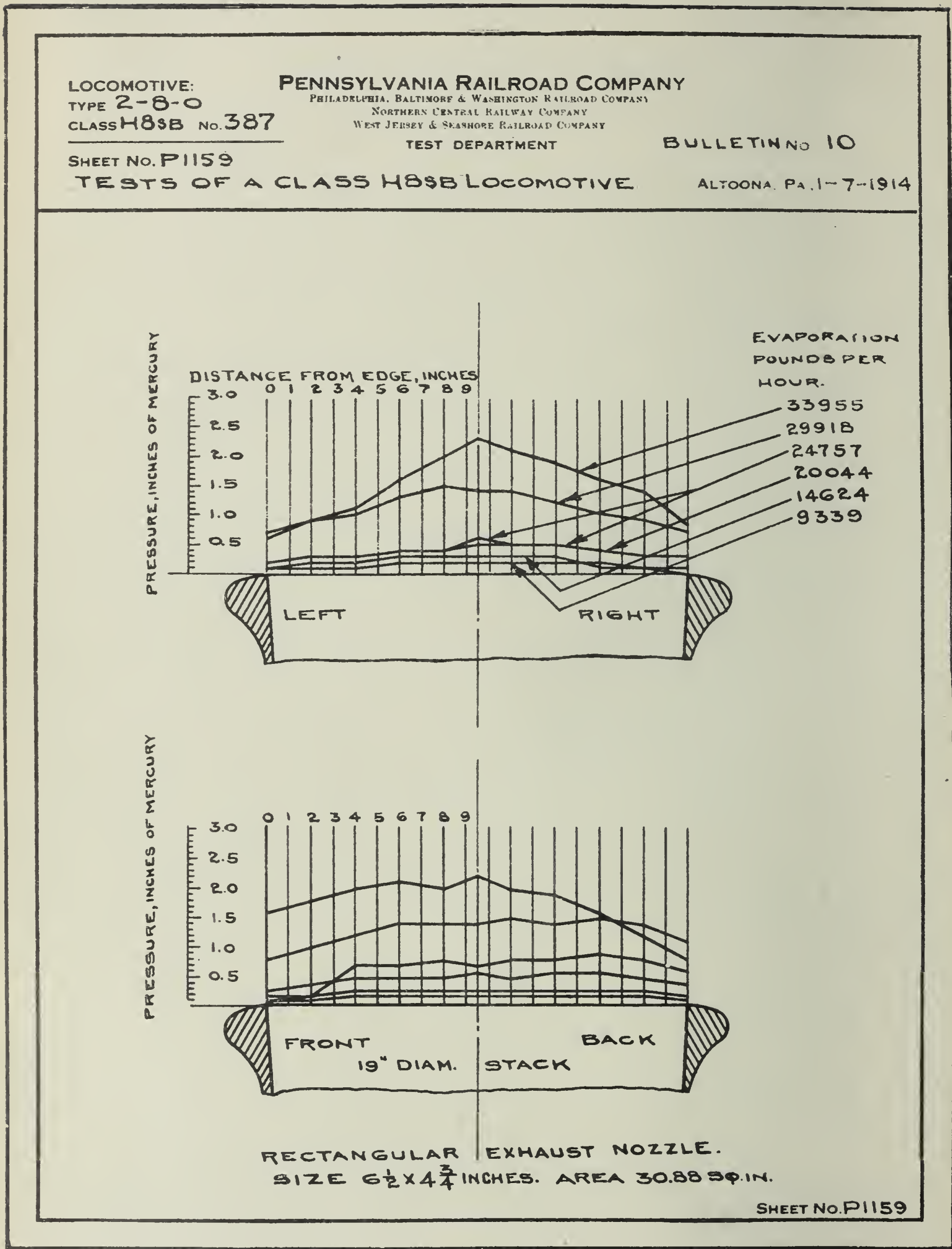

Fig. 17.

STACK PRESSURES.

These pressures indicate a uniform distribution of the gases across the stack opening in almost every instance, showing that the stack was completely filled.

52. The diagrams as a whole indicate the stack to have been completely filled and the pressures quite uniform.

53. The front end arrangement during these tests was as shown in Fig. 8. It was found to discharge all of the cinders, except a small bank about 8 inches high immediately in front of the nozzle. With this arrangement the area of opening under the table plate or diaphragm, where it crosses the steam pipes and exhaust nozzle was 3.15 square feet, while the opening under the forward edge of this plate was 3.88 square feet. The smallest opening was then not at the outlet for the gases, but back of it.

54. After the tests recorded in this Bulletin were completed, the table plate was raised up at the back so that the opening under it at the steam pipes and exhaust column was increased to 4.34 square feet. The front opening remained the same as before, 3.88 square feet, or 54 per cent., of the opening through the tubes. With this change, the front end gave fully as good results in cleaning and steaming as before. The final arrangement as shown in Fig. 10 is to be preferred, as the point of greatest restriction to the flow of gases is at the forward edge of the table plate, where the proper area of opening can be easily maintained.

Evaporation.

55. The evaporative performance is given in Table VII, showing the total pounds of water evaporated per hour to range from 9300 pounds to 33,900 pounds, while the equivalent evaporation per pound of dry coal varies between the same limits from 12.15 pounds to 5.37 pounds. The superheat in the branch pipe shows an increase from 97.32 degrees to 210.25 degrees Fahr. The boiler efficiency ranged between 81 and 37 per cent.

56. There is given in Table VIII, the evaporation rate for both boiler and superheater. Referring to this table it is seen that the equivalent evaporation for the boiler alone ranges from 11,329 to 41,255 pounds per hour, from and at 212 degrees Fahr.,

M. P. 479—A

351J 1-24 13
8 x 10½

LOCOMOTIVE:
TYPE 2-8-0
CLASS H8sb No. 387

PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

TEST DEPARTMENT

Bulletin No. 10

SHEET NO. P-1157

Tests of a Class H8sb Locomotive. ALTOONA, PA. 1-7-1914

SMOKEBOX GASES.

Test No.	Test Design-ation	Dura-tion of Test Mins.	Analysis of Smokebox Gases: Oxygen O Percent	Carbon Monoxide C O Per cent	Carbon Dioxide CO_2 Percent	Nitrogen N Per cent	Calorific Value of Dry Coal B.t.u.per Pound	Percent of Heat in Coal lost by pre-sence of C O	Temper-ature of Smoke Box	Smoke Percent Ringel-mann Scale
			253	254	255	256	248		207	
3207	40-20-F	120	4.5	0.0	11.8	83.0	14661	0.0	488	6
3206	60-20-F	105	4.24	0.16	12.96	82.64	14661	0.67	480	10
3205	60-20-F	75	3.7	0.1	13.9	82.3	14661	0.39	500	10
3210	40-30-F	120	4.6	0.3	13.2	81.9	14661	1.21	528	12
3201	80-20-F	120	4.9	0.3	13.3	81.5	14661	1.21	564	14
3209	60-30-F	90	2.6	0.28	14.96	82.16	14661	1.00	522	14
3223	120-20-F	120	0.9	2.3	16.5	80.3	13843	7.09	539	10
3227	60-35-F	90	2.1	0.5	14.9	82.4	13330	1.93	548	14
3202	80-30-F	90	2.8	0.7	14.4	82.1	14661	2.52	599	12
3212	100-25-F	120	1.5	0.4	15.7	82.4	14661	0.39	568	14
3228	170-20-F	120	0.5	0.8	15.6	82.2	13330	2.95	563	14
3208	100-25-F	60	1.9	0.5	13.6	84.2	14661	1.92	610	8
3211	100-25-F	30	1.8	0.4	15.2	82.6	14661	1.31	573	14
3204	80-40-F	105	3.3	0.3	13.9	82.4	14661	1.17	626	18
3225	140-25-F	90	0.4	0.6	16.4	82.6	13330	2.13	611	12
3203	80-40-F	30	4.2	0.2	13.6	82.0	14661	0.75	645	20
3221	120-30-F	120	0.2	0.8	16.5	82.5	13843	2.59	595	14
3246	40-75-F	30	2.2	2.0	14.4	81.4	14140	6.83	658	26
3214	100-40-F	120	0.8	1.0	15.2	82.9	13843	3.59	627	20
3213	100-40-F	30	0.2	1.4	15.8	82.6	14661	4.28	624	22
3229	160-30-F	120	2.2	1.2	15.8	80.8	13330	4.28	537	16
3218	140-35-F	120	-	-	-	-	13843	-	634	34
3215	100-45-F	120	0.3	1.5	15.4	82.9	13843	5.11	637	22
3230	120-40-F	120	3.2	1.0	14.5	81.2	13330	3.92	618	20
3247	40-88-F	15	2.4	2.0	14.0	81.6	14140	6.81	660	42
3238	80-55-F	30	6.5	2.3	11.8	79.4	13330	9.84	645	30
3222	160-35-F	60	0.9	2.3	16.5	80.3	13843	6.07	650	34
3224	170-35-F	60	0.3	0.2	15.8	83.7	13330	0.78	662	20
3242	60-68-F	30	5.2	1.0	12.6	81.2	14140	4.14	655	36
3236	100-50-F	60	0.6	0.7	17.3	81.4	13330	2.35	646	24
3220	140-40-F	60	0.3	1.3	16.3	82.1	13843	4.30	634	26
3245	60-75-F	30	6.2	1.4	11.6	80.8	14140	5.83	670	42
3216	120-50-F	60	0.3	1.3	15.9	81.5	13843	4.39	640	30
3239	80-58-F	60	5.3	1.9	12.3	80.5	13330	8.00	637	30
3237	100-55-F	60	0.5	1.3	17.1	81.1	13330	4.28	651	30
3235	160-40-F	60	0.5	0.3	17.3	79.9	13330	1.03	651	28
3217	120-50-F	45	0.3	2.6	15.5	81.6	13843	8.30	646	30
3244	60-86-F	15	3.6	2.0	13.2	81.2	14140	7.45	673	44
3241	80-63-F	60	6.3	0.5	12.3	80.9	13330	2.35	669	30

SHEET NO. P-1157

Table VI.

SMOKEBOX GASES.

The tests are arranged according to the evaporation rate. The loss due to carbon monoxide in the gases was small, due to careful hand-firing and the presence of an arch in the firebox; the smoke density was low.

M. P. 479—A

8 x 10½
851 4-29-12

LOCOMOTIVE:
TYPE 2-8-0
CLASS H8sb No. 387

PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

TEST DEPARTMENT

Bulletin No. 10

SHEET NO. P-1160

Tests of a Class H8sb Locomotive. ALTOONA, PA. 1-7-1914

EVAPORATIVE PERFORMANCE

Test No.	Test Designation	Duration of Test Mins.	Water and Steam: Total Lbs. of Water Evap.	Water and Steam: Pounds of Water Evaporated Per Hour	Evaporative Performance: Total Water Divided by Total Coal	Evaporative Performance: Equiv. Evap. Per Pound of Dry Coal	Superheat in branch Pipe Degrees Fahr.	Equiv. Evap. Lbs. Per Hour	Efficiency of Boiler
			264	340		347	230	344	350
3207	40-20-F	120	18678	9339	9.55	12.15	97.32	11880	80.42
3206	60-20-F	105	21186	12106	8.89	11.41	108.92	15523	75.52
3205	60-20-F	45	9558	12744	8.69	11.13	101.20	16333	73.67
3210	40-30-F	120	25991	12996	8.86	11.44	130.64	16777	75.72
3201	80-20-F	120	29247	14624	8.01	10.40	125.59	18926	68.60
3209	60-30-F	90	24741	16494	8.11	10.45	130.05	21250	69.17
3223	120-20-F	120	35877	17939	8.36	10.77	126.77	23107	75.51
3227	60-35-F	90	28506	19004	8.10	10.43	134.96	24459	75.93
3202	80-30-F	90	29654	19769	7.94	10.31	132.76	25659	68.24
3212	100-25-F	120	40087	20044	8.20	10.72	154.25	26193	70.95
3228	170-20-F	120	40422	20211	6.92	8.99	145.70	26279	65.45
3208	100-25-F	60	20757	20757	8.49	11.11	157.00	27161	73.54
3211	100-25-F	30	10479	20958	7.15	9.31	157.41	27286	61.62
3204	80-40-F	105	41243	23567	7.39	9.66	152.14	30804	63.94
3225	140-25-F	90	35778	23852	7.35	9.67	176.34	31393	70.40
3203	80-40-F	30	12108	24216	8.26	10.78	144.98	31610	71.35
3221	120-30-F	120	49513	24757	7.22	9.41	155.56	32282	65.96
3246	40-75-F	30	13133	26266	7.48	9.82	170.79	34476	67.39
3214	100-40-F	120	52635	26318	6.39	8.40	176.20	34609	58.88
3213	100-40-F	30	13455	26910	6.65	8.70	155.46	35199	57.58
3229	160-30-F	120	55730	27865	6.75	8.89	182.10	36727	64.72
3218	140-35-F	120	57104	28552	5.62	7.32	162.70	37320	51.31
3215	100-45-F	120	57197	28599	5.95	7.83	179.67	37630	54.89
3230	100-40-F	120	58521	29261	6.19	8.15	188.46	38558	59.33
3247	40-88-F	15	7441	29764	4.97	6.53	171.32	39050	44.81
3238	80-55-F	30	14959	29918	5.12	6.73	179.32	39339	48.99
3222	160-35-F	60	30244	30244	5.93	7.74	167.47	39499	54.26
3224	170-35-F	60	30826	30826	6.33	8.33	185.03	40581	60.64
3242	60-68-F	30	15441	30882	5.31	6.97	172.90	40588	47.83
3236	100-50-F	60	30959	30959	6.32	8.38	200.64	41030	61.00
3220	140-40-F	60	31681	31681	5.98	7.83	168.88	41510	54.89
3245	60-75-F	30	15924	31848	4.10	5.37	165.71	41664	36.85
3216	120-50-F	60	31621	31621	5.48	7.24	192.52	41797	50.75
3239	80-58-F	60	31606	31606	5.25	6.96	194.54	41847	50.67
3237	100-55-F	60	32556	32556	5.57	7.34	185.38	42900	53.43
3235	160-40-F	60	32666	32666	5.85	7.71	193.93	43086	56.13
3217	120-50-F	45	24766	33021	5.77	6.91	196.48	43306	48.44
3244	60-86-F	15	8444	33776	4.97	6.54	182.01	44456	44.88
3241	80-63-F	60	33955	33955	6.60	8.80	210.25	45256	64.06

SHEET NO. P-1160

Table VII.

EVAPORATIVE PERFORMANCE.

This locomotive evaporated from 9300 to 33,900 pounds of water per hour, while the equivalent evaporation per pound of dry coal ranged between 12.15 and 5.37 pounds.

M. P. 479-A 351J 1-24 13 8 x 10½

LOCOMOTIVE:
TYPE 2-8-0
CLASS H8sb No. 387

PENNSYLVANIA RAILROAD COMPANY
PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY
TEST DEPARTMENT

Bulletin No. 10

SHEET No. P-1162

Tests of a Class H8sb Locomotive. ALTOONA, PA. 1-7-1914

EVAPORATION RATE, BOILER AND SUPERHEATER.

Test No.	Test Designation	Water Evaporated Pounds Per Hour	Equivalent Evaporation from and at 212°F. lb. per Hour						Ratio of Equiv. Evap. in Boiler and Superheater per Sq.ft. of H.S.
			Boiler Excluding Superheater	Superheater Alone	Boiler Including Superheater	Per sq.ft. of Heating Surface			
						Boiler Excluding Superheater	Superheater Alone	Boiler Including Superheater	
		340			344			345	
3207	40-20-F	9339	11329	551	11880	3.73	0.681	3.09	0.182
3206	60-20-F	12106	14725	798	15523	4.85	0.986	4.04	0.203
3205	60-20-F	12744	15527	806	16333	5.12	0.996	4.22	0.194
3210	40-30-F	12996	15773	1004	16777	5.20	1.241	4.37	0.238
3201	80-20-F	14624	17834	1092	18926	5.55	1.344	4.76	0.242
3209	60-30-F	16494	19982	1368	21250	5.59	1.690	5.53	0.256
3223	120-20-F	17939	21763	1344	23107	7.18	1.661	6.01	0.231
3227	60-35-F	19004	22936	1523	24459	7.56	1.882	6.37	0.249
3202	80-30-F	19769	24092	1567	25659	7.95	1.936	6.68	0.243
3212	100-25-F	20044	24399	1794	26193	8.03	2.217	6.82	0.263
3228	170-20-F	20211	24558	1721	26279	8.09	2.127	6.84	0.262
3208	100-25-F	20757	25251	1910	27161	8.33	2.360	7.07	0.283
3211	100-25-F	20958	25368	1918	27286	8.37	2.370	7.10	0.283
3204	80-40-F	23567	28717	2087	30804	9.47	2.579	8.02	0.272
3225	140-25-F	23852	28986	2407	31393	9.56	2.975	8.17	0.311
3203	80-40-F	24216	29565	2045	31610	9.75	2.527	8.23	0.259
3221	120-30-F	24757	30043	2239	32282	9.91	2.767	8.40	0.279
3246	40-75-F	26266	31910	2566	34476	10.53	3.171	8.98	0.301
3214	100-40-F	26318	31955	2654	34609	10.54	3.280	9.04	0.311
3213	100-40-F	26910	32760	2439	35199	10.81	3.014	9.19	0.278
3229	160-30-F	27865	33818	2909	36727	11.16	3.594	9.59	0.322
3218	140-35-F	28552	34659	2661	37320	11.43	3.289	9.74	0.287
3215	100-45-F	28599	34683	2947	37630	11.44	3.642	9.81	0.318
3230	120-40-F	29261	35448	3110	38558	11.69	3.844	10.04	0.328
3247	40-88-F	29764	36027	3023	39050	11.89	3.736	10.17	0.314
3238	80-55-F	29918	36261	3078	39339	11.96	3.804	10.24	0.318
3222	160-35-F	30244	36697	2802	39499	12.11	3.463	10.28	0.285
3224	170-35-F	30826	37380	3201	40581	12.33	3.956	10.57	0.320
3242	60-68-F	30882	37545	3043	40588	12.39	3.761	10.57	0.303
3236	100-50-F	30959	37608	3422	41030	12.41	4.229	10.68	0.340
3220	140-40-F	31681	38454	3056	41510	12.69	3.777	10.81	0.297
3245	60-75-F	31848	38665	2999	41664	12.76	3.707	10.85	0.290
3216	120-50-F	31621	38381	3416	41797	12.66	4.222	10.88	0.333
3239	80-58-F	31606	38394	3453	41847	12.67	4.268	10.90	0.337
3237	100-55-F	32556	39507	3393	42900	13.03	4.194	11.17	0.321
3235	160-40-F	32666	39481	3605	43086	13.03	4.456	11.22	0.341
3217	120-50-F	33021	40043	3263	43306	13.21	4.033	11.28	0.305
3244	60-86-F	33776	41006	3450	44456	13.53	4.264	11.58	0.314
3241	80-63-F	33955	41255	4001	45256	13.61	4.945	11.78	0.363

SHEET No. P-1162

Table VIII.

EVAPORATION RATE, BOILER AND SUPERHEATER.

The ratio of equivalent evaporation in the boiler to that in the superheater per square foot of heating surface increases from 0.182 to 0.363. Thus, it may be assumed that 27.25 per cent. of the equivalent evaporation per square foot of heating surface takes place in the superheater.

while for the superheater the range is from 551 to 4001 pounds per hour. Thus, for both boiler and superheater, the total equivalent evaporation increases from 11,880 to 45,256 pounds per hour as the boiler is gradually forced to the maximum limit.

57. The equivalent evaporation per square foot of heating surface for boiler and superheater ranges from 3.09 to 11.78 pounds per hour, which is low for this locomotive, due to the poor grate performance at the high rates of combustion.

58. The ratio of equivalent evaporation in the boiler to that of the superheater per square foot of heating surface ranges from 0.182 to 0.363. Thus, we may reasonably assume by referring to this last column in Table VIII, that 27.25 per cent. of the equivalent evaporation per square foot of heating surface takes place in the superheater, or in other words, the rate of heat transfer per unit of superheating surface is 27.25 per cent. of that of the boiler surface. The superheating surface in this locomotive is 22.8 per cent. of the total heating surface in the boiler.

59. The relation existing between the water evaporated in pounds per hour and the dry coal fired in pounds per hour is shown in Fig. 18. As the rate of combustion increases from 1000 to 7500 pounds of dry coal fired per hour, the evaporation rate is seen to increase gradually from 9200 to 34,400 pounds per hour.

60. Fig. 19 shows the increase in the rate of evaporation as the draft is increased. This was likewise characteristic of the combustion rate as shown in Fig. 14.

61. The range of steam temperature in the branch pipe, boiler, and superheater, together with their respective pressures at the different rates of equivalent evaporation, are given in Fig. 20. It is observed that the superheat increases almost directly with the evaporation rate and that the maximum superheat reached 210 degrees Fahr. for one test. The general range of superheat, shown by the curve varied between 96 and 196 degrees Fahr., which is rather low.

62. When 25,000 pounds of water are evaporated per hour the steam pressure starts to drop when passing through the super-

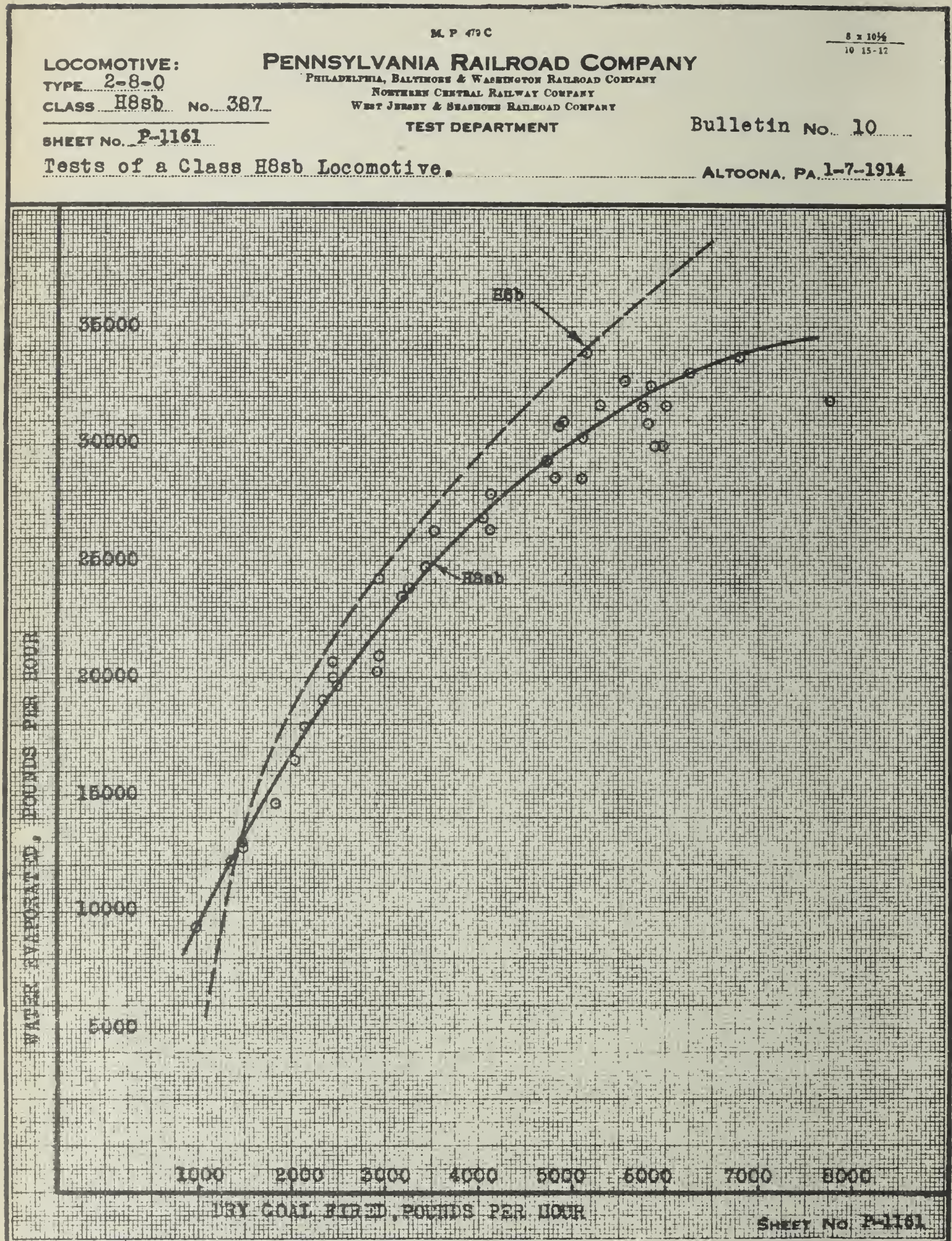

Fig. 18.

COAL FIRED AND WATER EVAPORATED.

The H8b saturated steam locomotive evaporates more water per thousand pounds of coal burned than the H8sb superheated steam locomotive. This is on account of the former having a greater water heating surface.

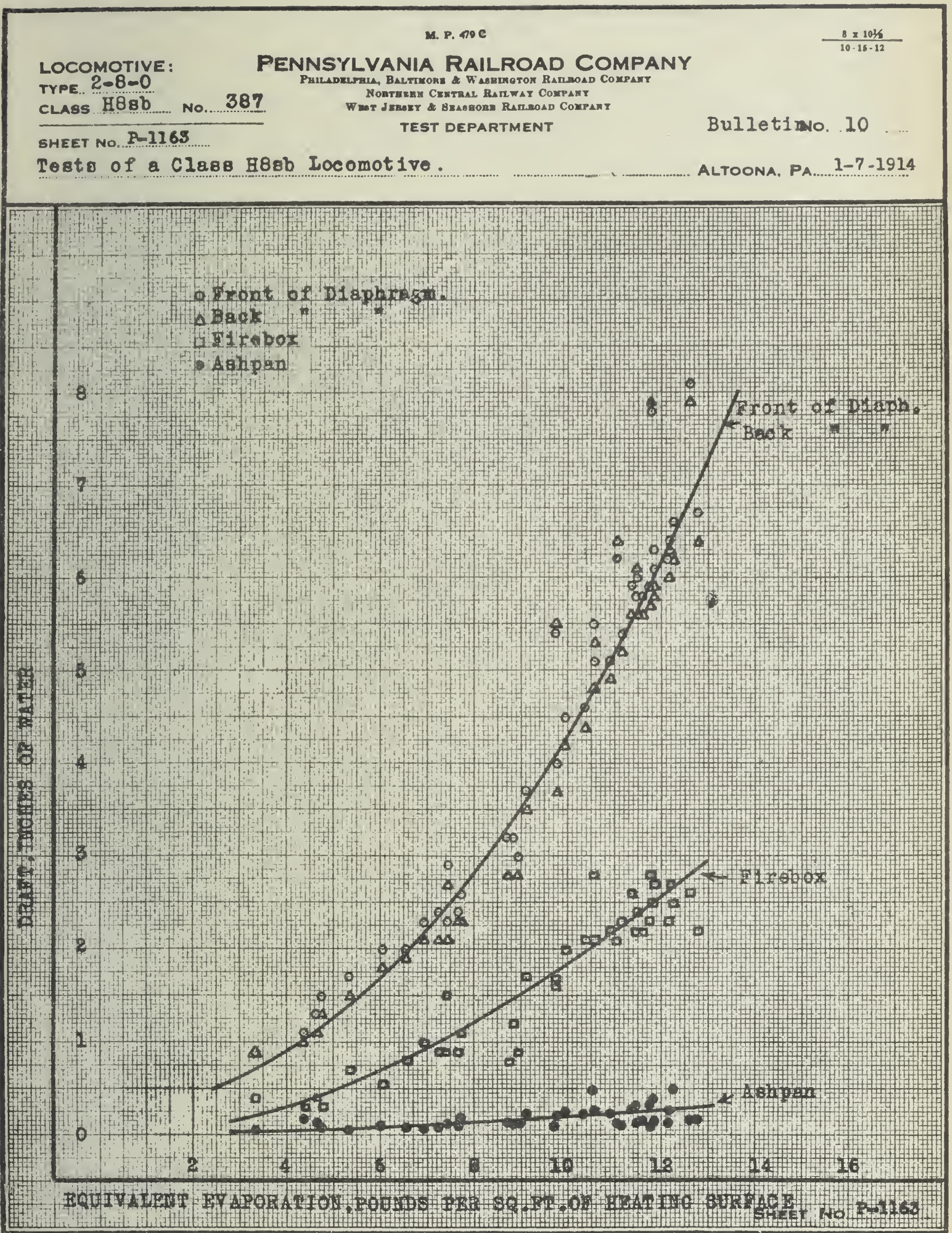

Fig. 19.

DRAFT AND EQUIVALENT EVAPORATION PER SQUARE FOOT OF HEATING SURFACE.

This diagram shows the increase in the rate of evaporation as the draft is increased.

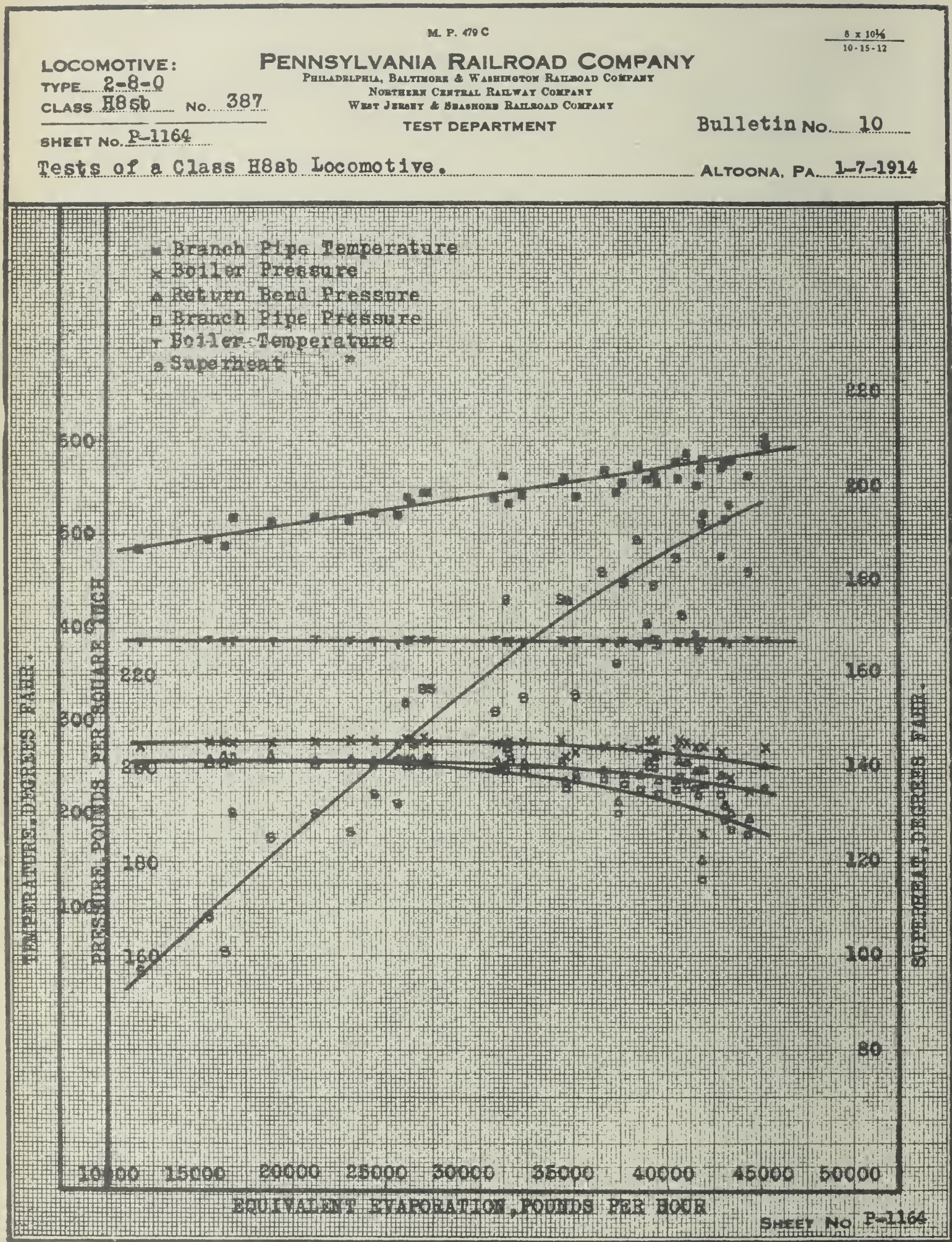

Fig. 20.

TEMPERATURE AND PRESSURE OF STEAM WITH A DROP IN PRESSURE BETWEEN BOILER AND CYLINDERS.

The superheat increases almost directly with the evaporation rate. The steam when passing through the superheater units has a practically constant pressure, until the rate of evaporation exceeds 25,000 pounds of water per hour. There is a gradual loss in pressure at the higher rates, amounting to 14 pounds at the highest rate of evaporation.

heater units, and at the highest rate of evaporation this pressure loss amounts to about 14 pounds.

Equivalent Evaporation.

63. The equivalent evaporation per pound of dry coal and the amount of dry coal fired per hour are shown in Fig. 21. The curve is a straight line which may be expressed by the equation $E = 12.8 - (0.053)\ C$, where "C" is the dry coal fired per hour, in pounds per square foot of grate.

64. It is seen that the equivalent evaporation per pound of dry coal decreases from 12 to 5.3 pounds as the rate of combustion is increased from 17 to 140 pounds of dry coal per square foot of grate per hour.

65. As between the H8b saturated and H8sb superheated steam locomotive, Fig. 21 shows the evaporations to be equal for a rate of combustion of about 55 pounds of coal per square foot of grate per hour, but when this rate is increased to 140 pounds the evaporation of the saturated steam locomotive is in excess of that of the superheater by about seven per cent., this excess diminishing as the rate of combustion is decreased.

66. When the combustion rate drops below 55 pounds, the evaporation falls below that obtained from the superheated steam locomotive.

67. The fact that the H8b saturated steam locomotive has a larger evaporating surface than the H8sb boiler accounts for this increase in the evaporation per pound of coal.

68. The performance of the two boilers at equal rates of evaporation is shown in Fig. 22. The better performance of the saturated steam boiler is again demonstrated from this evaporative standpoint. When the equivalent evaporation per square foot of heating surface is 9 pounds per hour, the increase in the equivalent evaporation in pounds of water per pound of dry coal obtained from the saturated steam boiler is 16 per cent.; above that and on toward higher rates the curves parallel each other, and the decrease in the rates of evaporation is practically constant.

69. Table IX gives the equivalent evaporation per square foot of grate surface per hour and per square foot of heating surface per hour, in addition to the total boiler horse-power developed, the boiler horse-power per square foot of heating surface, per square foot of grate surface and the efficiency of the boiler.

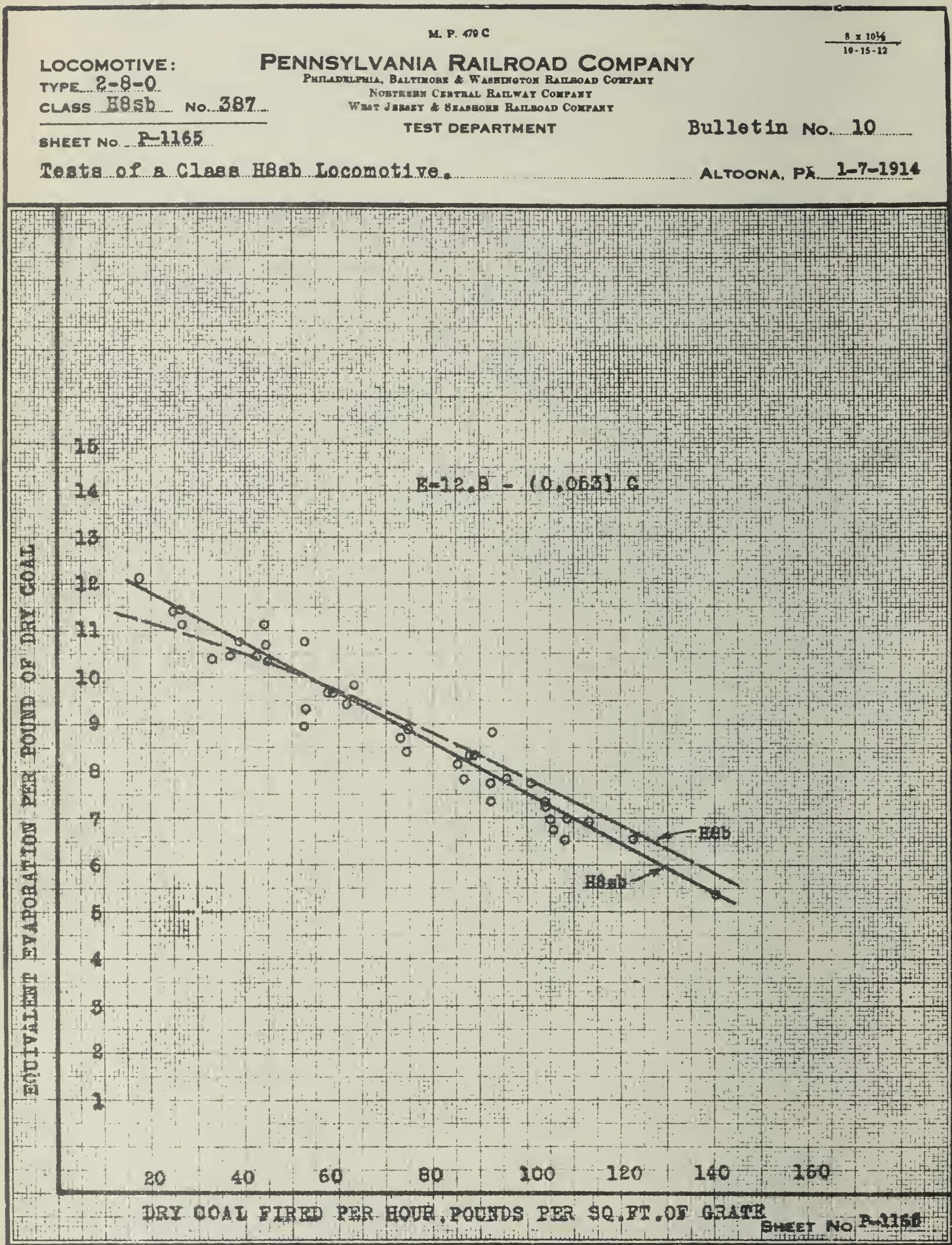

Fig. 21.

DRY COAL FIRED AND EQUIVALENT EVAPORATION PER POUND DRY COAL.

The equivalent evaporation per pound of dry coal for the H8b saturated steam locomotive exceeds that obtained from the H8sb superheated steam locomotive by approximately 7 per cent. when the combustion rate is 140 pounds of dry coal per square foot of grate per hour.

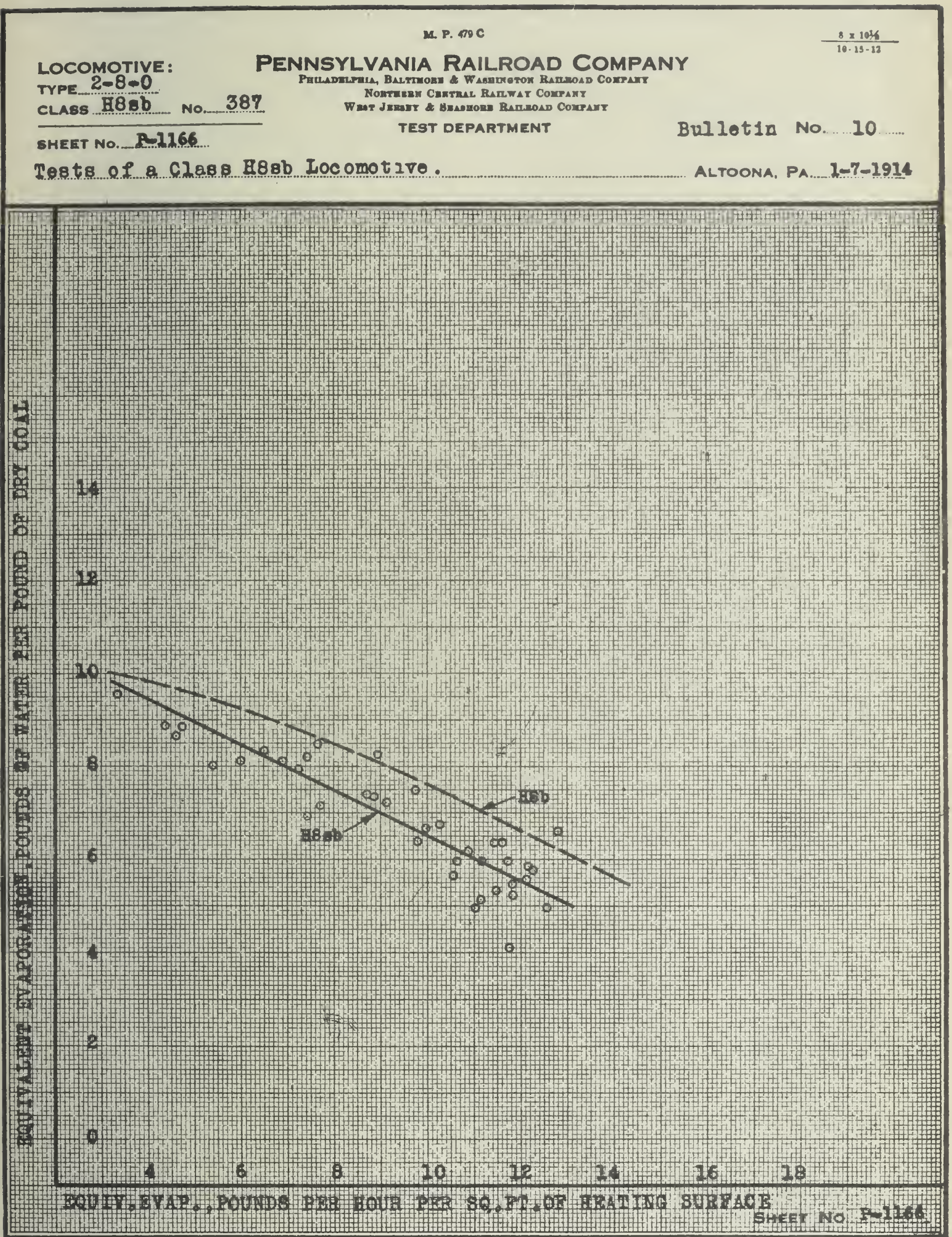

Fig. 22.

EQUIVALENT EVAPORATION AND EVAPORATION PER SQUARE FOOT OF HEATING SURFACE.

The better performance of the saturated steam boiler from an evaporative standpoint, due to its larger evaporating surface, is again shown.

70. The equivalent evaporation per square foot of grate surface per hour ranged between 214.67 and 817.78 pounds. Based on the heating surface the equivalent evaporation ranged between 3.36 and 12.80 pounds.

71. The boiler horse-power increased from 344.3 to 1311.8, and its efficiency decreased from 80.42 to 36.85 per cent. It may be observed that Test No. 3241, having a greater boiler horse-power and equivalent evaporation per square foot of heating surface per hour than Test No. 3244, also has an efficiency of 64.06 per cent. or nearly 20 per cent. greater than the boiler efficiency obtained from Test No. 3244.

72. The coal used in the two tests was obtained from different cars, and an analysis showed the heating value of the coal used in Test No. 3241 to approximate 13,330 B.t.u. per pound of dry coal, while that in Test No. 3244 gave 14,140 B.t.u.

Boiler Efficiency.

73. As the rate of firing is increased the decrease in the boiler efficiency is graphically shown by a straight line in Fig. 23. The relation thus existing between the boiler efficiency and the combustion rate in pounds of dry coal fired per square foot of grate per hour may be expressed by an equation, $E = 87 - (0.35)\ C$, where "C" is the pounds of dry coal fired per hour per square foot of grate.

74. On this diagram is shown a curve or straight line for the H8b saturated locomotive boiler. A comparison between the superheated steam boiler and saturated steam boiler shows the efficiency for the latter to exceed that of the former at corresponding rates of combustion by 10 per cent. The only difference existing between the two locomotive boilers is that the H8sb boiler has a Schmidt type fire-tube superheater.

75. Fig. 24 illustrates the relation as shown by a curve, between the boiler efficiency and the total water evaporated expressed in pounds per hour.

76. Comparing this curve with the one immediately above, representing the H8b saturated steam boiler, it is observed that the efficiency of the superheated steam boiler is less and drops off more rapidly as the evaporation rate increases.

77. The same fact in Fig. 24 is again presented by Fig. 25, in which the basis is the rate of equivalent evaporation in pounds

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LOCOMOTIVE
TYPE 2-8-0
CLASS H8sb No. 387

PENNSYLVANIA RAILROAD COMPANY
PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

TEST DEPARTMENT

Bulletin No. 10

SHEET No. P-1167

Tests of a Class H8sb Locomotive. ALTOONA, PA. 1-7-1914

BOILER POWER

Test No.	Test Designation	Duration of Test Mins.	Equiv. Evap. Pounds Per sq. ft. of Grate Per Hour	Equiv. Evap. Pounds Per sq. ft. of Heating Surface Per Hour	Boiler Horse Power Total	Boiler Horse Power Per sq. ft. of Heating Surface	Boiler Horse Power Per sq. ft. of Grate Surface	Efficiency of Boiler
				345	349			350
3207	40-20-F	120	214.67	3.36	344.3	0.097	6.22	80.42
3206	60-20-F	105	280.50	4.39	449.9	0.127	8.13	75.52
3205	60-20-F	75	295.13	4.62	473.4	0.134	8.55	73.67
3210	40-30-F	120	303.16	4.74	486.3	0.138	8.79	75.72
3201	80-20-F	120	341.99	5.40	548.6	0.155	9.91	68.60
3209	60-30-F	90	383.99	6.01	615.9	0.174	11.13	69.17
3223	120-20-F	120	417.54	6.53	669.8	0.189	11.21	75.51
3227	60-35-F	90	441.97	6.92	709.0	0.201	12.81	75.93
3202	80-30-F	90	463.66	7.26	743.7	0.210	13.44	68.24
3212	100-25-F	120	473.31	7.41	759.2	0.215	13.72	70.95
3228	170-20-F	120	474.86	7.43	761.7	0.216	13.76	65.45
3208	100-25-F	60	490.89	7.68	787.3	0.222	14.22	73.54
3211	100-25-F	30	493.06	7.72	790.9	0.224	14.27	61.62
3204	80-40-F	105	556.63	8.71	892.9	0.252	16.13	63.94
3225	140-25-F	90	567.28	8.88	909.9	0.257	14.44	70.40
3203	80-40-F	30	571.19	8.94	916.2	0.259	16.56	71.35
3221	120-30-F	120	583.34	9.13	935.7	0.264	16.91	65.96
3246	40-75-F	30	622.80	9.75	999.3	0.282	18.06	67.39
3214	100-40-F	120	625.38	9.79	1003.2	0.284	18.13	58.88
3213	100-40-F	30	636.05	9.95	1020.3	0.289	18.44	57.58
3229	160-30-F	120	663.66	10.38	1064.6	0.301	19.43	64.72
3218	140-35-F	120	674.37	10.55	1081.7	0.306	19.55	51.31
3215	100-45-F	120	679.98	10.64	1090.7	0.308	19.71	54.89
3230	120-40-F	120	696.74	10.90	1117.6	0.311	20.19	59.33
3247	40-88-F	15	705.85	11.04	1131.9	0.320	20.45	44.81
3238	80-55-F	30	710.85	11.12	1140.3	0.322	20.61	48.99
3222	160-35-F	60	711.95	11.17	1144.9	0.323	20.69	54.26
3224	170-35-F	60	733.30	11.47	1176.3	0.333	21.26	60.64
3242	60-68-F	30	733.43	11.48	1176.5	0.333	21.26	47.83
3236	100-50-F	60	741.41	11.60	1189.3	0.336	21.49	61.00
3220	140-40-F	60	750.09	11.74	1203.2	0.340	21.74	54.89
3245	60-75-F	30	752.87	11.78	1207.7	0.341	21.82	36.85
3216	120-50-F	60	755.28	11.82	1211.5	0.343	21.89	50.75
3239	80-58-F	60	756.18	11.83	1213.0	0.343	21.92	50.67
3237	100-55-F	60	775.21	12.13	1243.5	0.352	22.47	53.43
3235	160-40-F	60	778.57	12.18	1248.9	0.353	22.57	56.13
3217	120-50-F	45	782.54	12.25	1255.2	0.355	22.68	48.44
3244	60-86-F	15	803.32	12.57	1288.6	0.364	23.29	44.88
3241	80-63-F	60	817.78	12.80	1311.8	0.379	23.71	64.06

SHEET NO. P-1167

Table IX.

BOILER POWER.

The boiler horse-power increased from 344.3 to 1311.8 and the efficiency decreased from 80.42 to 36.85 per cent.

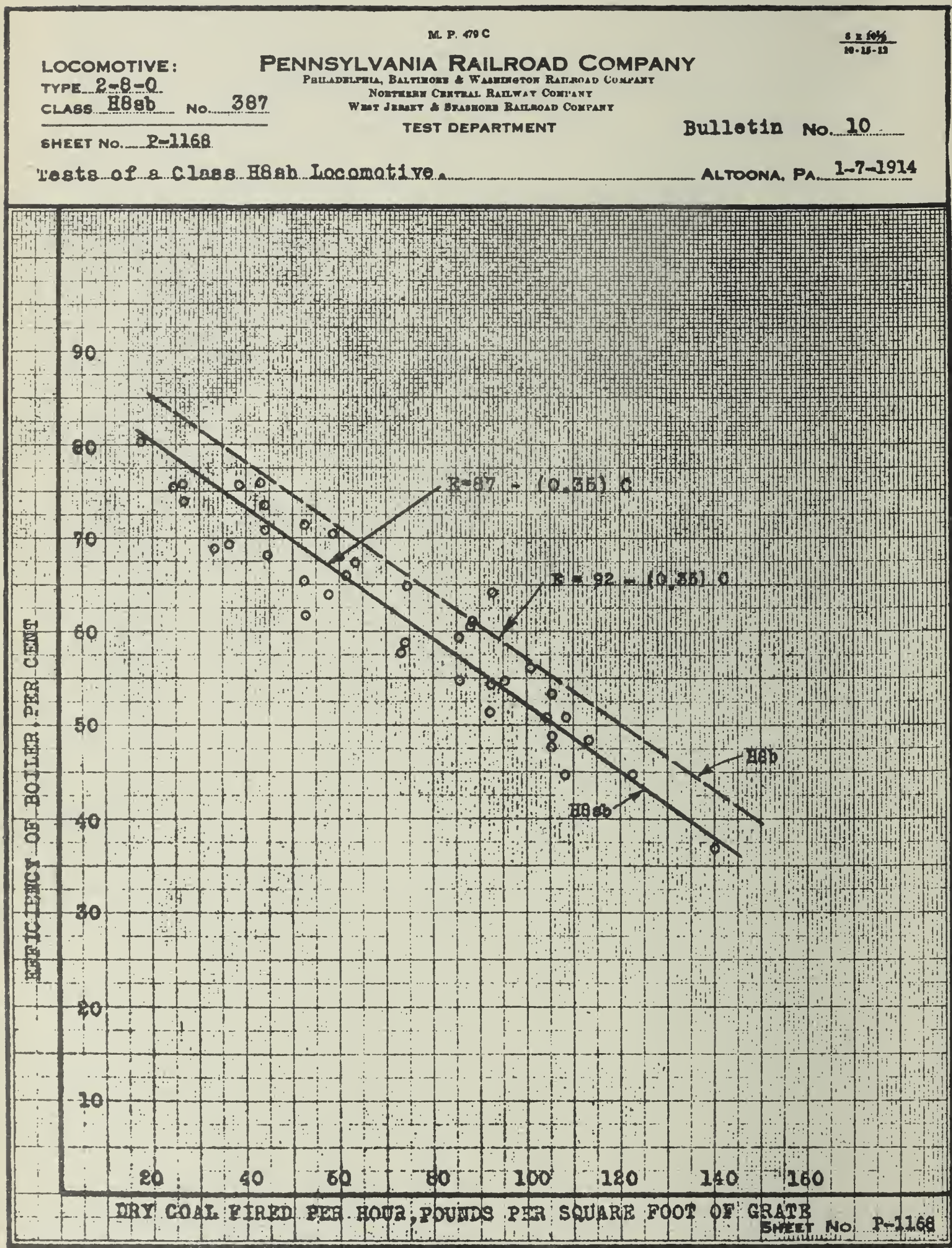

Fig. 23.

EFFICIENCY OF BOILER AND RATE OF FIRING.

The boiler efficiency of the H8b saturated steam locomotive exceeds that of the H8sb superheated steam locomotive by 10 per cent. at corresponding rates of combustion.

per square foot of grate per hour, instead of actual total evaporation per hour; the difference between the two figures being practically one of scale only.

Steam Passages.

78. The steam passages from the boiler to the exhaust nozzle are important in the design of a superheated steam locomotive. The superheater elements offer a considerable resistance to the flow of the steam and produce a drop in pressure between the boiler and branch pipe.

79. Fig. 26 is given to show in a graphical way the areas of these passages at points where restrictions occur. The area of the passage is shown by the solid portion, the velocity by the cross-hatched space, and the pressure is indicated by the open space.

80. The velocity of the steam flow for each of the several passages at their points of greatest restriction was computed from data obtained from Test No. 3241, or the one having the maximum rate of evaporation, namely 33,955 pounds of water per hour. There being no unusually small passages, the steam velocity does not exceed 6000 feet per minute.

81. The average boiler pressure obtained during this test No. 3241 was 204.7 pounds. The duration of test was one hour.

82. The pressure in the superheater header, saturated side, was 203 pounds. At the return bend, or the middle of the superheater length, the pressure was 200.7 pounds, and the final pressure obtained in the branch pipe was 195.9 pounds. The drop in pressure thus obtained at the maximum steam flow was 8.8 pounds, or 4.3 per cent., of the boiler pressure.

Boiler Tube Temperature.

83. Temperatures, for each foot of length, within the boiler tubes and superheater flues were taken during this series of tests. As described in Bulletin 21, these temperatures were obtained with a long thermo-couple which could be inserted in the tube or flue to any desired point.

84. The temperatures obtained are presented on Figs. 27 to 32, inclusive. On these diagrams are also given the firebox and smokebox temperatures taken at the same time. All temperatures are given in degrees Fahrenheit.

85. The firebox temperatures range between 1920 and 2400 degrees and the temperatures at the tube ends range between

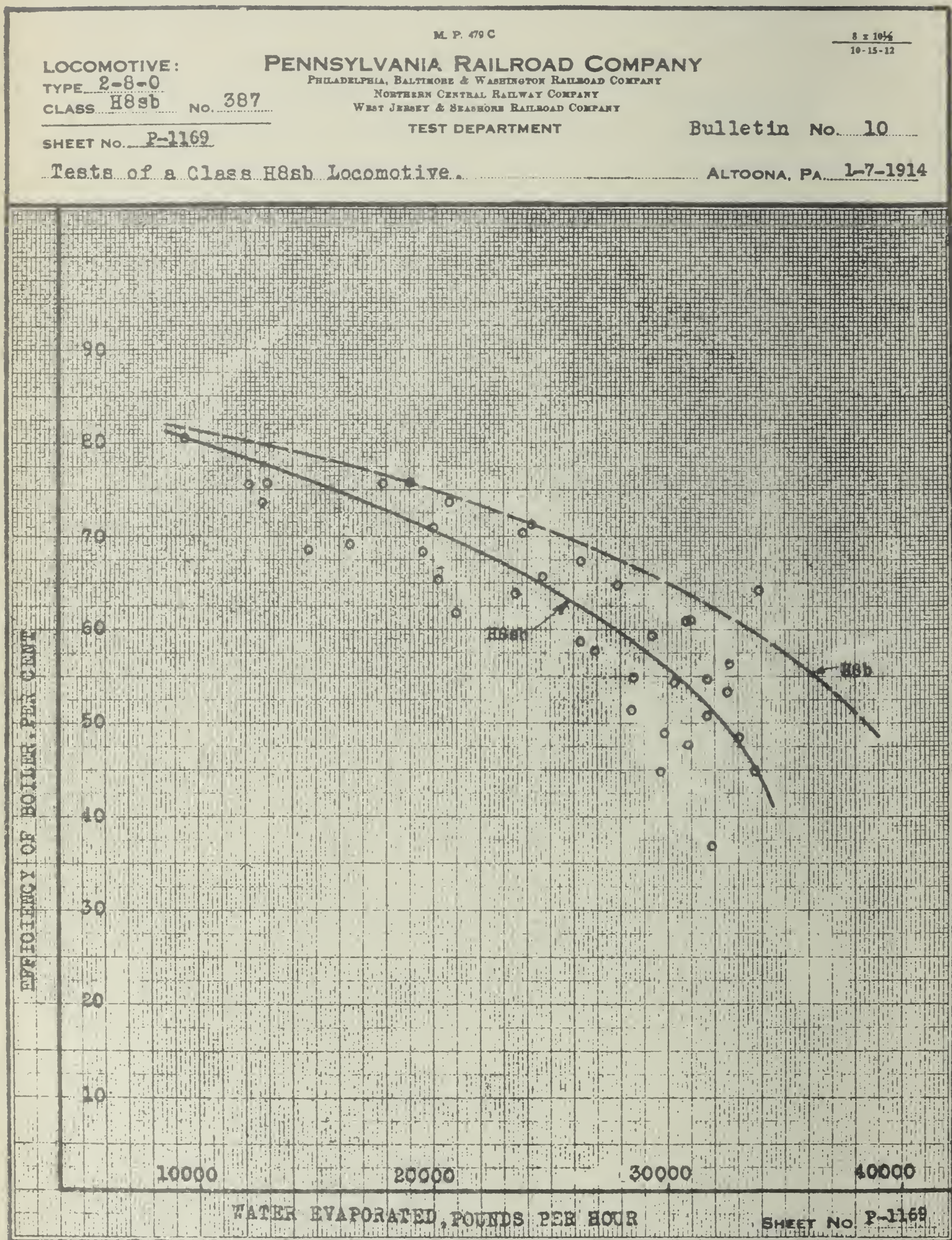

Fig. 24.

EFFICIENCY OF BOILER AND EVAPORATION RATE.

Comparing the boiler efficiencies of the saturated steam and superheater boilers, the efficiency of the H8sb superheater boiler is lower and drops off more rapidly as the rate of evaporation increases.

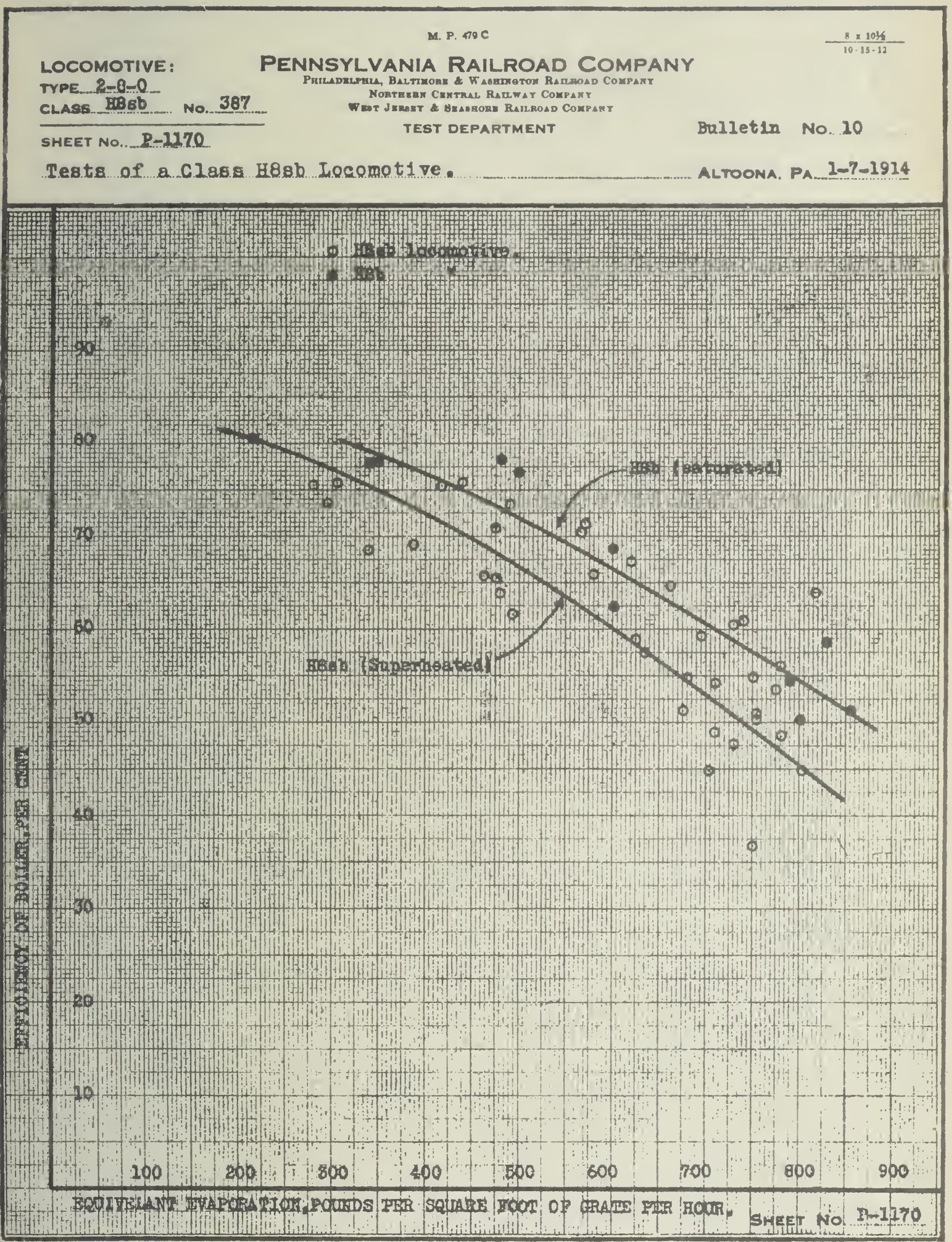

Fig. 25.

EFFICIENCY OF BOILER AND EQUIVALENT EVAPORATION PER SQUARE FOOT OF GRATE PER HOUR.

This diagram shows the same characteristics as Fig. 24.

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LOCOMOTIVE:
TYPE 2-8-0
CLASS H8sb NO. 387

PENNSYLVANIA RAILROAD COMPANY
PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

TEST DEPARTMENT

Bulletin No. 10

SHEET NO. P-1171

Tests of a Class H8sb Locomotive.

ALTOONA, PA. 1-7-1914

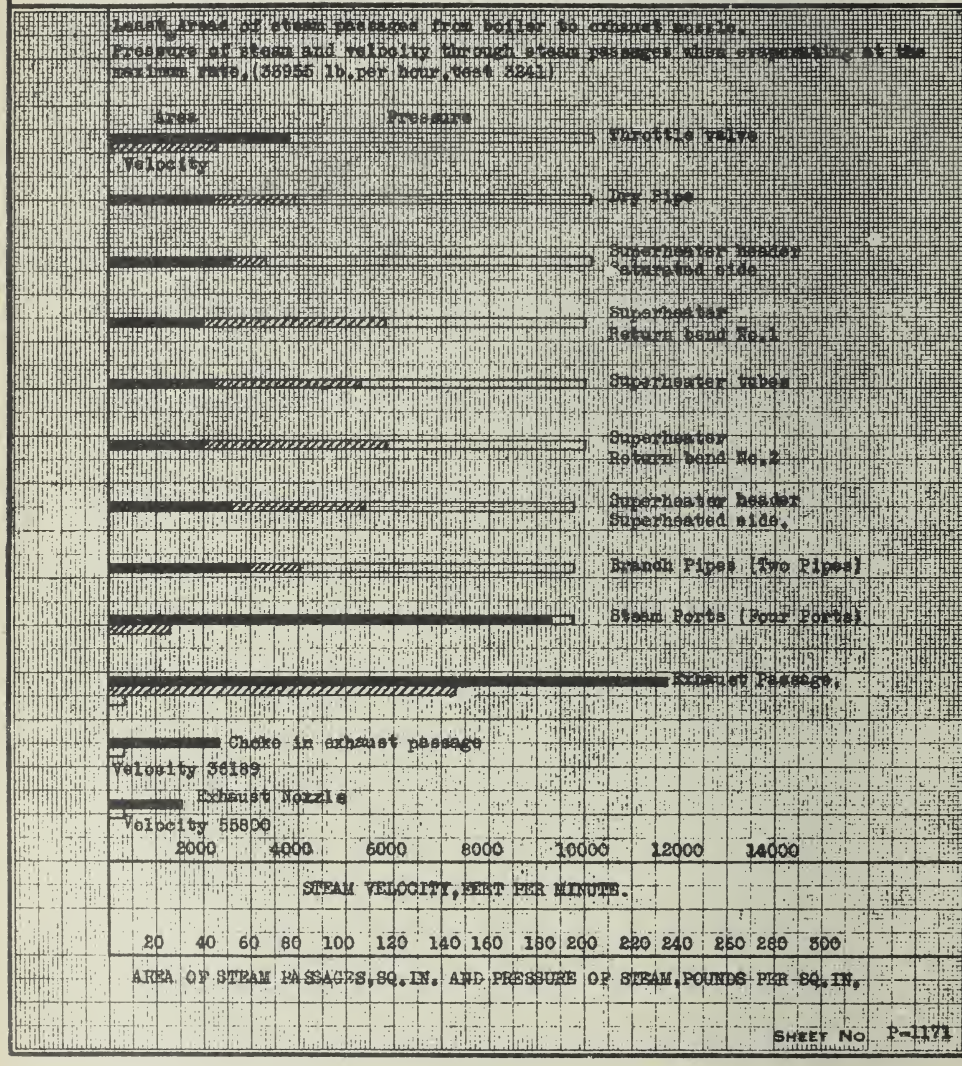

Fig. 26.

AREA OF STEAM PASSAGES.

This is a graphical representation of the restricted areas in the steam passages from the boiler to the exhaust nozzle. The area of the passage is shown by the black portion, the velocity of the steam by the cross-hatched space, and the steam pressure by the open space.

1320 and 2060 degrees. From the time the gases enter the tubes or flues until they leave at the smokebox end there is a rapid fall of temperature. The temperature of the gases as they leave the tubes at the smokebox end ranges between 500 and 650 degrees. The smokebox temperatures range between 480 and 660 degrees.

86. Referring to Figs. 27, 29 and 30 it is observed that the temperatures in the boiler tube and superheater flue at the firebox end are alike and remain so for the first 20 inches. The gases give up their heat at a slower rate when passing through the superheater flue than they do when passing through the boiler tube. The difference in temperature at the end of the tubes ranges between 40 and 80 degrees.

87. The temperature ranges throughout the boiler tube and the superheater flue were alike during a comparatively low power test, as shown by Fig. 28. The draft was light, being 1.8 inches of water. The evaporation rate per hour was but 16,494 pounds and the coal fired per hour amounted to only 2033 pounds; thus it was a comparatively light test.

88. A variation from the above tendency is shown by Fig. 31. Here the superheater flue temperature for the first 40 inches falls a little below that of the boiler tube; but for the remaining length and particularly for the middle portion of the tube the drop in temperature is considerably less rapid than that in the boiler tube. The difference in temperature at the smokebox end of the tube and flue is 240 degrees. In this particular instance it may be noted that the temperature in the smokebox end of the boiler tube was 160 degrees below the smokebox temperature. The draft for this test was 5.6 inches of water. The evaporation rate was 30,826 pounds of water per hour and the combustion rate was 4870 pounds of coal per hour.

89. On these several diagrams the rapid fall of the boiler tube temperature curves is especially noticeable, indicating that the tubes were rapidly absorbing the heat throughout their length, and transfering it to the water within the boiler. The length of the boiler tubes is 15 feet, or 103 internal diameters.

90. In the case of the superheater flues, at the higher rates of evaporation, a typical instance of which is shown on diagram No. 32, the drop is quite rapid for the first half of the length, whereafter the temperature fall is more gradual. The gases leave the superheater flues at the smokebox temperature or slightly above.

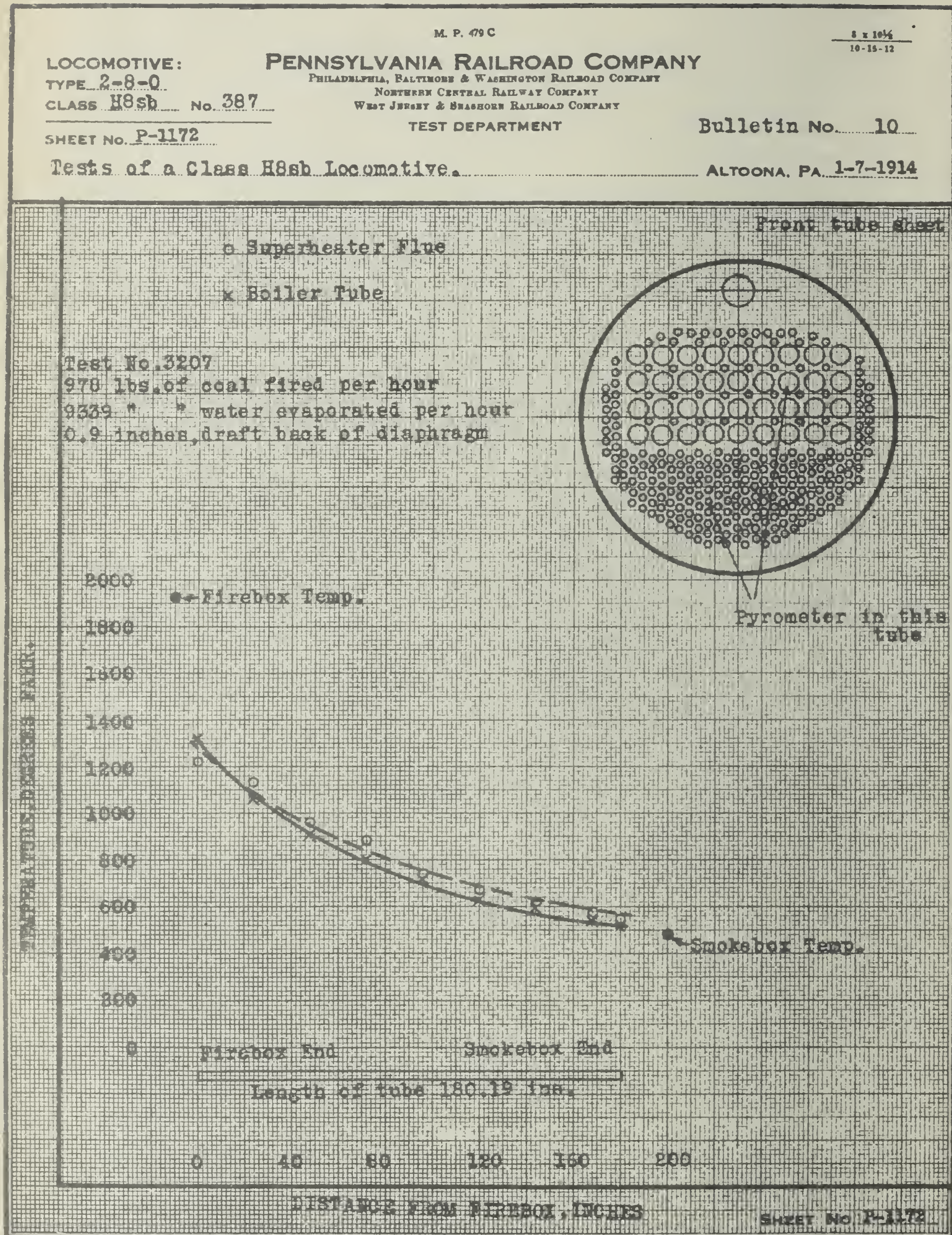

Fig. 27.

TEMPERATURES IN THE SUPERHEATER FLUE AND BOILER TUBE.

The rate of coal burning is 978 pounds per hour and the draft back of diaphragm is 0.9 inches of water.

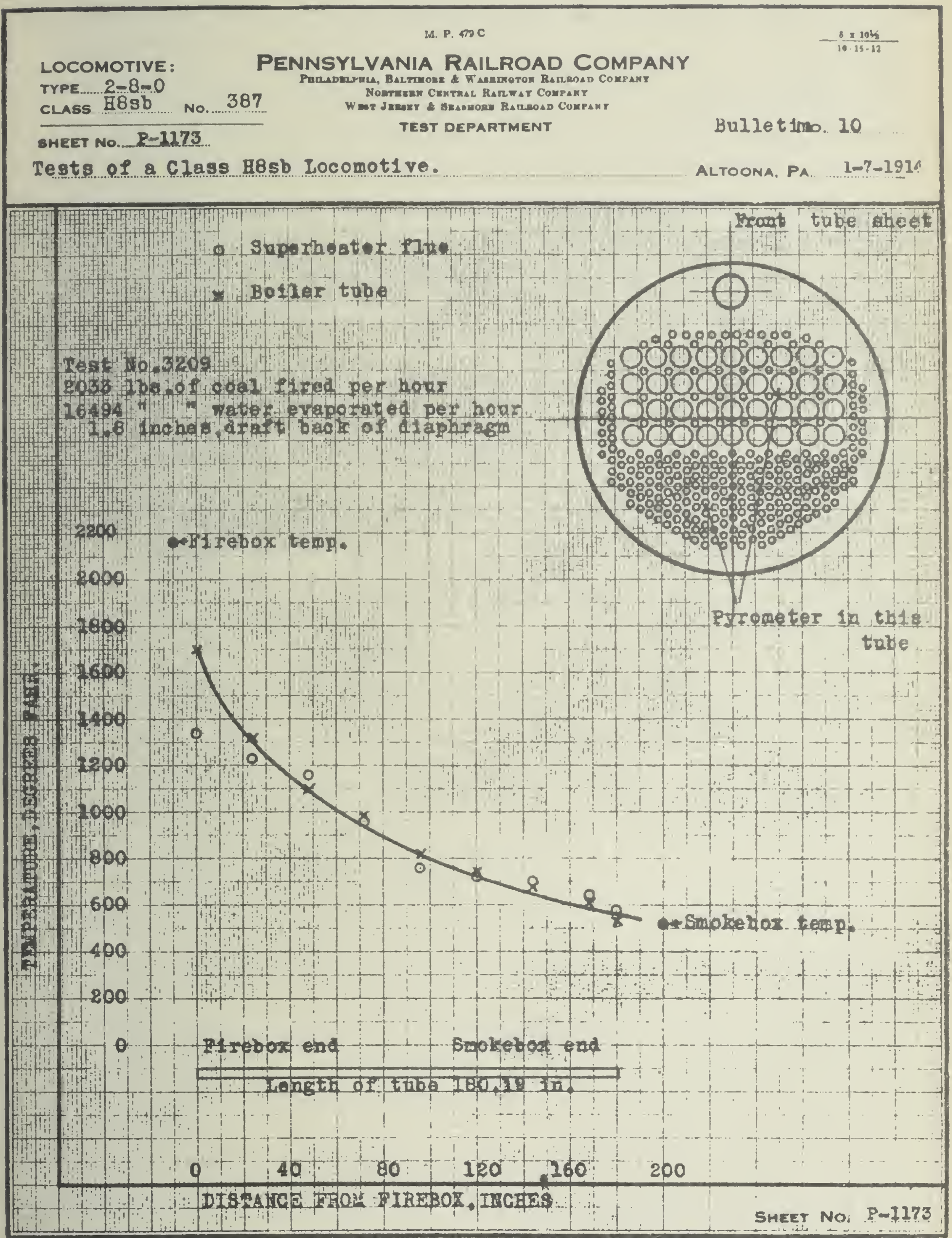

Fig. 28.

TEMPERATURE IN THE SUPERHEATER FLUE AND BOILER TUBE.

The temperature curves for the boiler tube and the superheater flue are parallel when the rate of combustion is 2033 pounds of coal fired per hour, and the draft is 1.8 inches of water back of diaphragm.

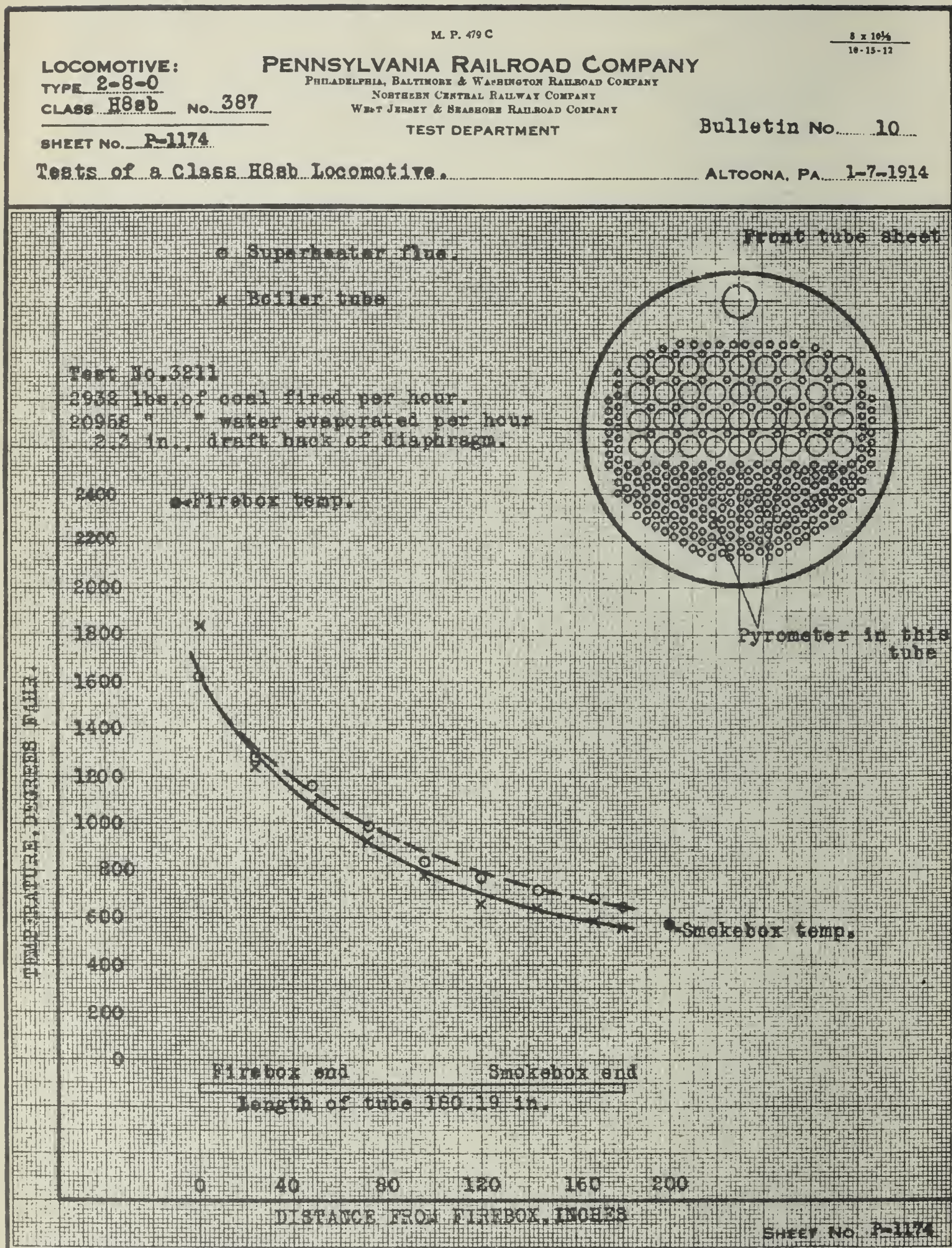

Fig. 29.

TEMPERATURES IN THE SUPERHEATER FLUE AND BOILER TUBE.

The temperatures shown here are for a rate of firing of 2932 pounds of coal per hour. The draft back of diaphragm is 2.3 inches of water.

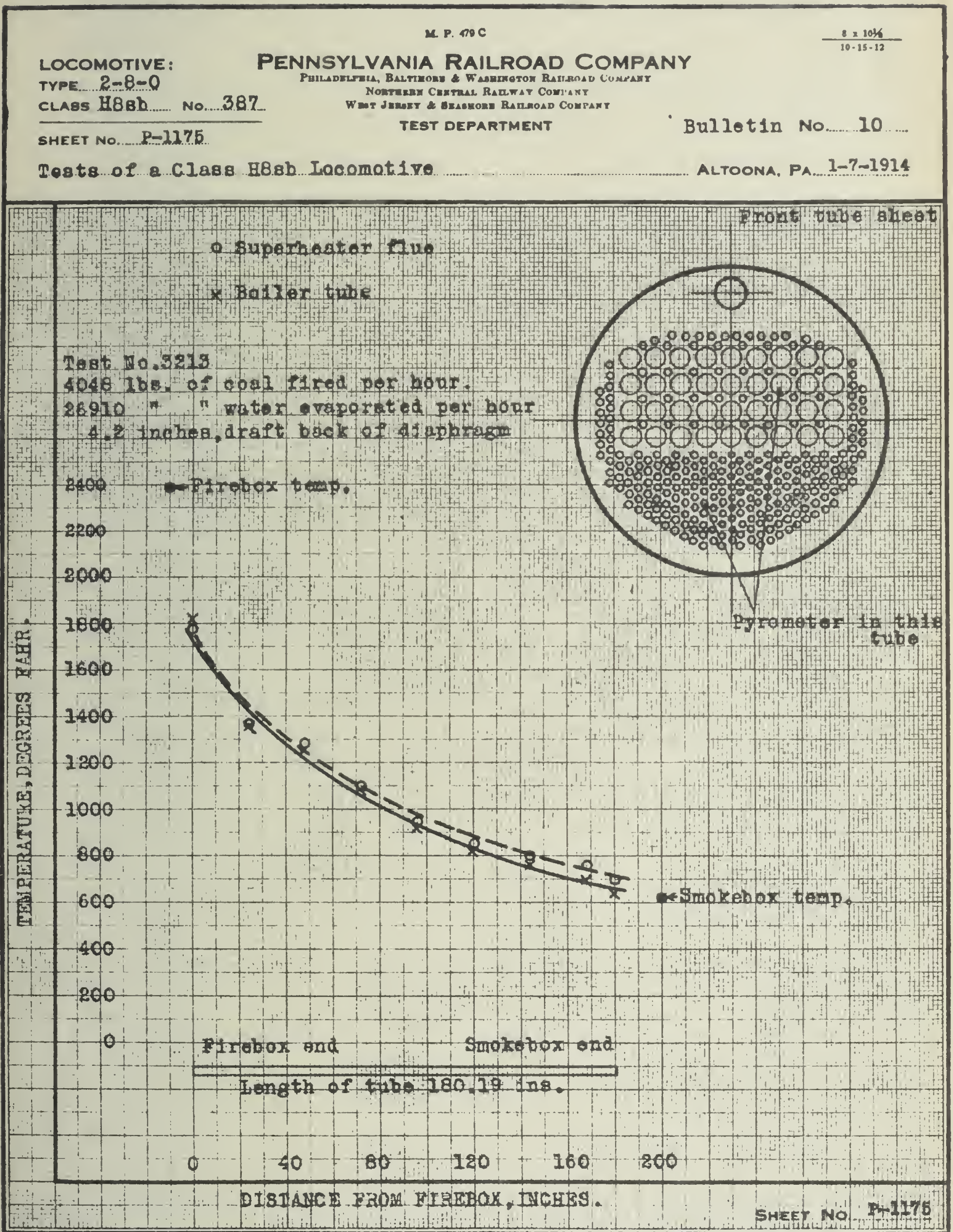

Fig. 30.

TEMPERATURES IN THE SUPERHEATER FLUE AND BOILER TUBE.

Similar to Figs. 27 and 29, it is shown here that the temperature in the boiler tube and superheater flue at the firebox end are alike for the first 20 inches. The difference in temperature at the end of the tube ranges between 40 and 80 degrees.

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TEST DEPARTMENT

LOCOMOTIVE:
TYPE 2-8-0
CLASS H8sb No. 387

SHEET No. P-1176

Bulletin No. 10

Tests of a Class H8sb Locomotive.

ALTOONA, PA. 1-7-1914

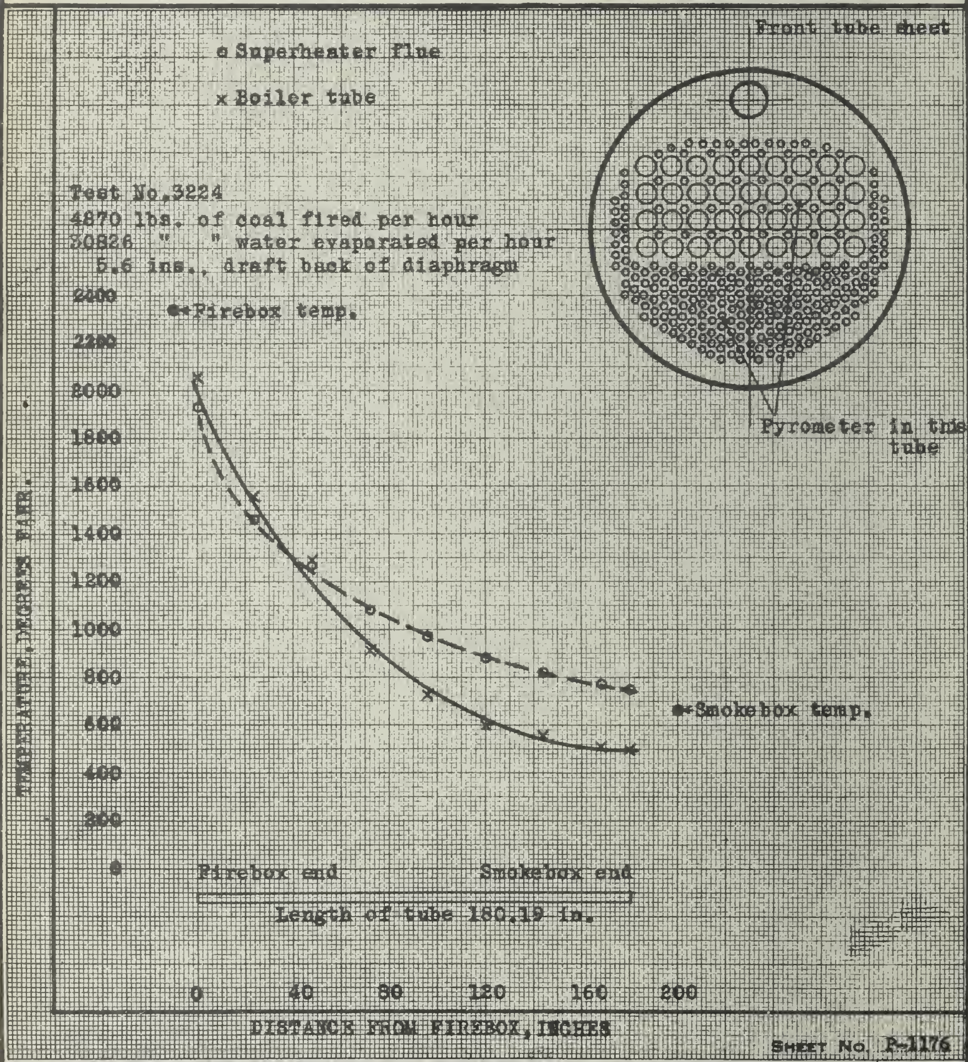

Fig. 31.

TEMPERATURES IN THE SUPERHEATER FLUE AND BOILER TUBE.

This diagram shows a variation from what is given in Figs. 27, 29 and 30. Here, the superheater flue temperature for the first 40 inches falls below that of the boiler tube temperature.

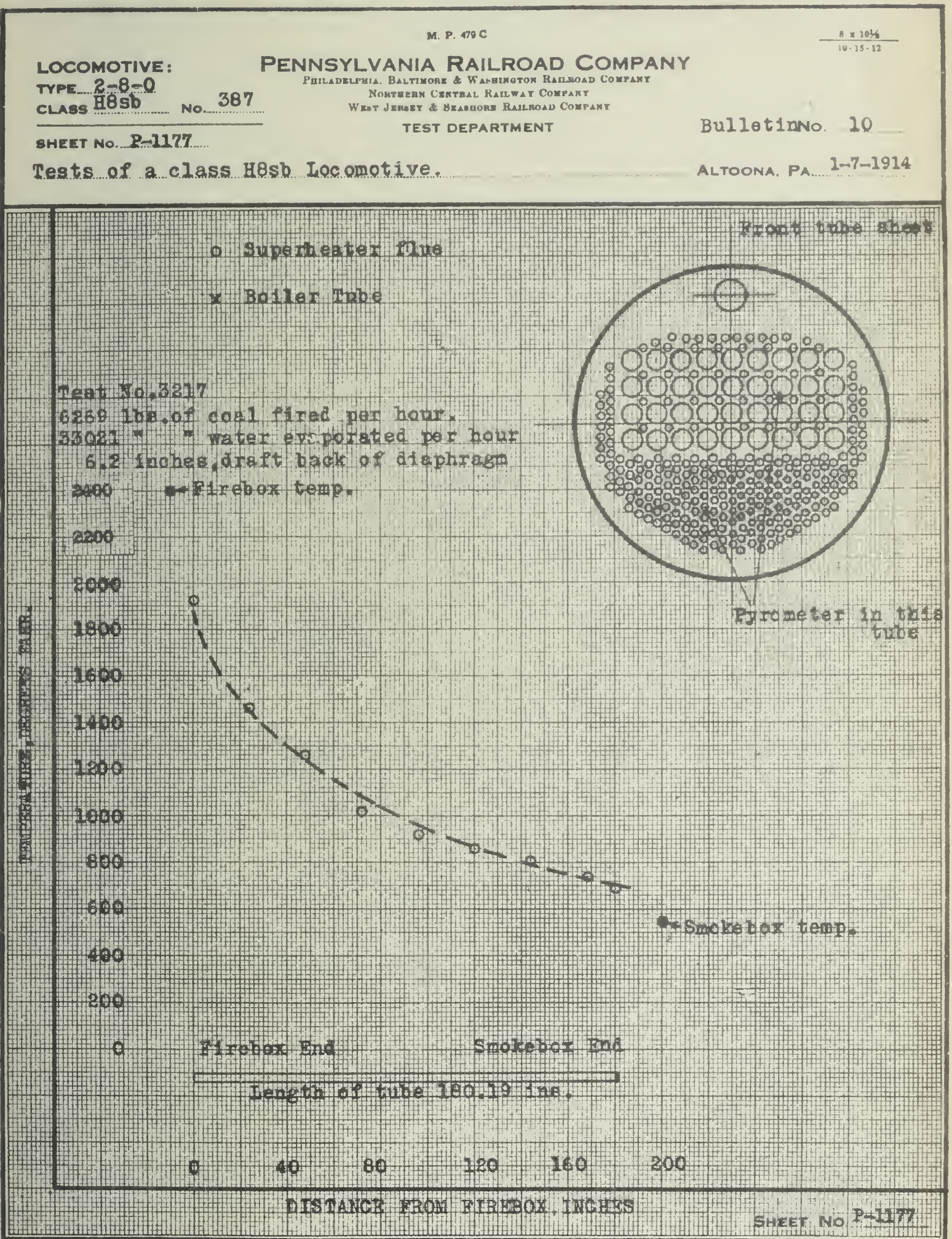

Fig. 32.

TEMPERATURES IN THE SUPERHEATER FLUE.

A typical instance showing the temperature drop in a superheater flue at the higher rates of evaporation. The gases leave the superheater flue at a temperature close to that of the smokebox.

91. The tendency is for the temperatures in the superheater flues and boiler tubes to increase with the rate of firing, as was found to be the case with other locomotives similarly tested on this plant. (See Bulletin No. 21, Fig. 36 and Par. 82.)

Heat Balance.

92. In making up the heat balance for the boiler in Bulletins Nos. 11, 18 and 21, the method was that of the American Society of Mechanical Engineers, as given in their boiler test code. In this Bulletin a method suggested by Mr. Lawford H. Fry has been used. This latter method contains fewer assumptions in the data used in the calculations.

93. The American Society of Mechanical Engineers heat balance was primarily worked up for stationary boiler use, and is based on one pound of dry coal as fired. The method suggested by Mr. Fry uses a number of constants obtained from locomotive experiments. One advantage of this method is that the heat balance is based on the dry coal fired per hour per square foot of grate.

94. The heat losses considered in the new method are loss by external radiation, loss by formation of CO in the firebox, loss of heat in the smokebox gases and the loss of unburnt combustible. The American Society of Mechanical Engineers code lists the losses as due to moisture in coal, moisture produced by burning hydrogen, heat in dry gases, incomplete combustion, ash and refuse, moisture in the air and radiation.

95. The heat absorbed by the boiler is similarly calculated in both methods, excepting that a loss due to radiation is considered in Mr. Fry's method. Five per cent. of the heat absorbed by the water is assumed to cover this loss.

96. In table X is presented the heat balance for this locomotive, computed from data given in table VI.

97. Table XI gives the heat losses in per cent. They are further presented graphically in Fig. 33. It is observed that as the boiler is forced the heat losses in the dry smokebox gases, the unburned fuel and those due to the vapor of combustion gradually increase.

98. The largest single loss is that due to unburned fuel caused by incomplete combustion as the rate of firing is increased. The percentage of loss increasing from a minimum of 1.49 per cent. when the rate of firing was 38.8 pounds of dry coal per hour per

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8 x 10½
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LOCOMOTIVE:
TYPE 2-8-0
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TEST DEPARTMENT

Bulletin No. 10

SHEET No. P-1178

Tests of a Class H8sb Locomotive.

ALTOONA, PA.,

HEAT BALANCE BASED ON DRY COAL FIRED PER HOUR PER SQ.FT.OF GRATE

Test No.	Pounds Dry Coal Fired Per Hr. Per Sq.ft. of Grate.	Heat Absorbed, B.t.u. Per Sq.ft. of Grate.	Heat Loss in B.t.u. per Sq.Ft. of Grate Per Hour.				Total	Total or B.t.u. in Dry Coal Fired Per hr. per sq.ft. of Grate
			Dry Smoke Box Gases.	Carbon Monoxide C O.	Due to Vapor of Combustion	Un-accounted For		
3206	24.6	285801	37270	2281	13901	25077	364333	360514
3205	26.5	300713	39005	1456	14864	36266	392304	388663
3201	33.0	348361	57302	5616	18646	35588	495468	483813
3223	38.8	425390	46086	36639	21936	8014	538065	537108
3202	45.0	472362	74610	16015	25475	81020	669482	659451
3228	52.8	483773	75127	19592	30030	115757	724277	703824
3204	57.6	567119	106483	9386	32802	154325	870115	844913
3225	58.7	577920	85818	15855	33726	80679	793998	782071
3221	62.0	594324	87869	22052	35207	145890	883342	858266
3214	74.4	637118	121428	35086	42832	238603	1075067	1030334
3229	74.6	676142	104339	43290	44951	156097	1024819	994817
3215	86.8	692750	137082	59122	49948	327852	1266754	1201572
3224	88.0	747159	154481	8156	50848	257823	1218467	1173040
3241	92.9	833154	202636	28028	53790	157851	1275459	1239023
3220	95.8	764175	143124	54023	54583	198532	1214437	1325744
3242	105.2	747261	211902	59373	60196	526521	1605253	1487528
3237	105.6	789851	157416	57150	60903	426076	1491396	1407648
3238	105.6	724234	203026	150629	60759	401073	1520291	1407648
3217	113.3	797289	167803	125190	65050	533670	1619002	1568135
3244	122.8	818686	227092	124415	70236	654896	1895325	1736392

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Table X.

HEAT BALANCE BASED ON DRY COAL FIRED PER HOUR PER SQUARE FOOT OF GRATE.

The heat losses are calculated in accordance with the method of Lawford H. Fry.

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TYPE 2-8-0
CLASS H8sb No. 387

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TEST DEPARTMENT

SHEET NO. P-1179

Bulletin No. 10

Tests of a Class H8sb Locomotive.

ALTOONA, PA. 1-7-1914

HEAT BALANCE BASED ON DRY COAL FIRED PER HOUR PER SQ. FT. OF GRATE

Test No.	Pounds Dry Coal Fired Per Hour Per Square Foot of Grate	Heat Absorbed in Per Cent	Heat Loss in Per Cent Due to: Dry Smoke Box Gases	Carbon Monoxide C O	Vapor of Combustion	Unburned Fuel	Total
3206	24.6	78.27	10.33	0.63	3.86	6.95	101.04
3205	26.5	77.65	10.03	0.37	3.82	9.33	101.20
3201	33.0	72.00	11.84	1.16	3.85	13.55	102.40
3223	38.8	79.20	8.58	6.82	4.08	1.49	100.17
3202	45.0	71.62	11.31	2.42	3.86	12.28	101.49
3228	52.8	68.73	10.67	2.78	4.26	16.44	102.88
3204	57.6	67.12	12.60	1.11	3.88	18.26	102.97
3225	58.7	73.89	10.97	2.02	4.31	10.31	101.50
3221	62.0	69.24	10.23	2.56	4.10	16.76	102.89
3214	74.4	61.83	11.78	3.40	4.15	23.15	104.31
3229	74.6	67.96	10.48	4.35	4.51	15.69	102.99
3215	86.8	57.65	11.40	4.92	4.15	27.28	105.40
3224	88.0	63.69	13.17	0.61	4.33	21.11	102.91
3241	92.9	67.24	16.35	2.26	4.34	12.74	102.93
3220	95.8	57.64	10.79	4.07	4.11	14.59	91.20
3242	105.2	50.23	14.24	3.99	4.04	35.39	107.89
3237	105.6	56.11	11.18	4.05	4.32	30.26	105.92
3238	105.6	51.44	14.42	9.28	4.31	28.54	107.99
3217	113.3	50.84	10.70	7.98	4.14	34.03	107.69
3244	122.8	47.14	13.07	7.16	4.04	37.71	109.12

SHEET NO. P-1179

Table XI.
HEAT BALANCE.
The items in Table X are here expressed as a percentage of the total.

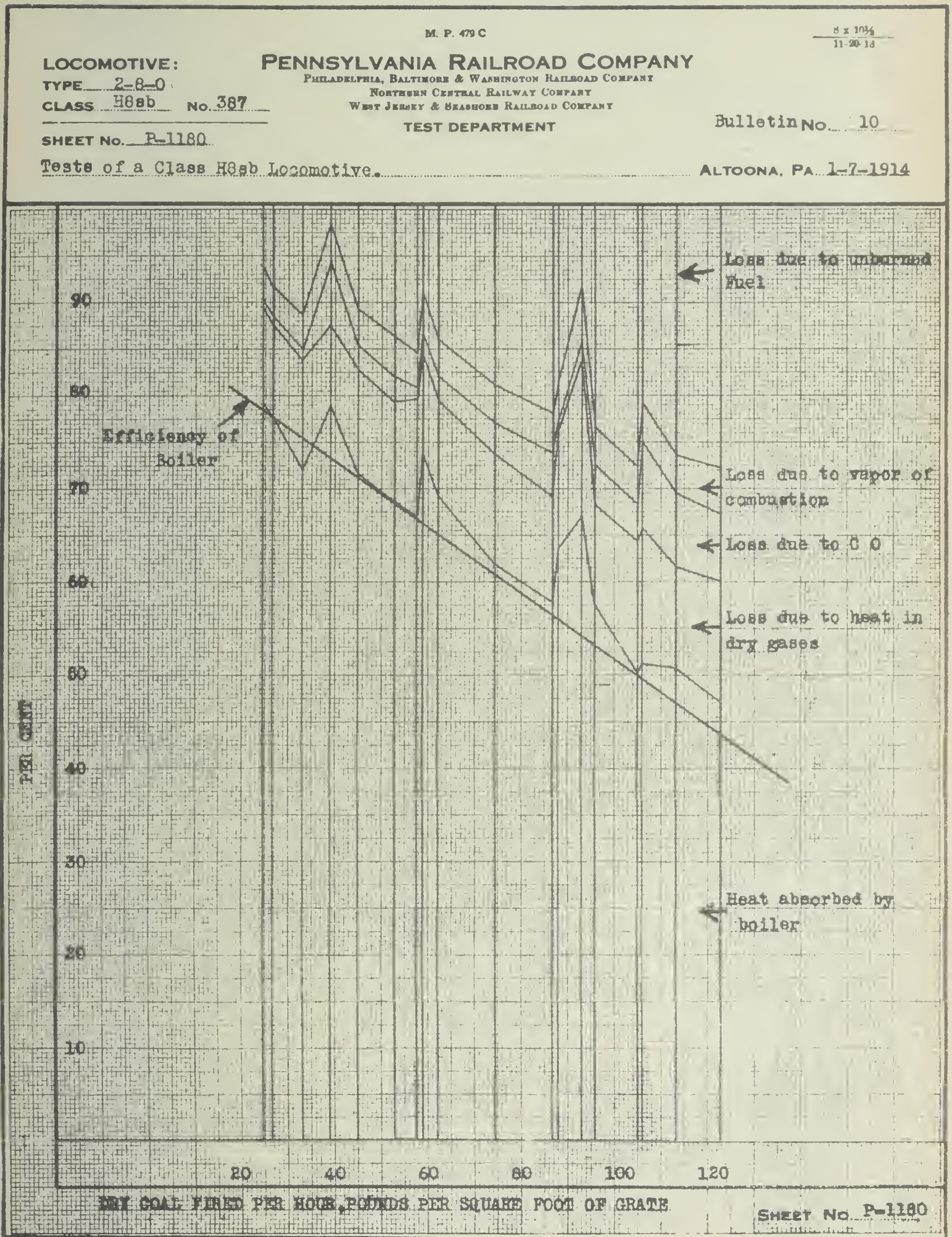

Fig. 33.

HEAT BALANCE.

The boiler absorbs from 47 to 79 per cent. of the heat in the coal. The largest single loss is that due to unburned fuel especially at the higher rates of combustion.

square foot of grate to 37.71 per cent. when 122.8 pounds of coal per hour per square foot of grate was fired.

99. The heat lost in the dry smokebox gases varies, throughout the different rates of firing, from 8.58 to 16.35 per cent. The average is 11.71 per cent.

100. The loss by CO due to a small air supply, in conjunction with the condition of the fire, varies from 0.37 per cent. to 9.28 per cent. With a properly drafted boiler we should expect no loss from this cause at low power and not over 2 to 3 per cent. of the heat in the coal fired at the maximum boiler output.

101. The loss incurred by the vapor of combustion has a tendency to increase with the increase in the rate of firing, namely, from 3.82 to 4.34 per cent.

102. The boiler absorbs from 47 to 79 per cent. of the heat in the coal.

Air Supply.

103. It was previously shown in this Bulletin (Fig. 13 and Par. 36) that when the combustion rate exceeded 5500 pounds of coal per hour or 100 pounds per square foot of grate per hour, the coal was not properly burned. Table XI substantiates this fact. Referring to this table it will be observed that at rates of firing exceeding 96 pounds of dry coal per square foot of grate per hour, the heat loss due to unburned fuel ranged from 1.49 to 37.71 per cent.

104. A probable cause for this incomplete combustion at the higher rates of firing is an insufficient air supply. This is apparent in Fig. 16, showing the carbon monoxide when plotted with the dry coal fired. This diagram shows the great rapidity with which the curve rises at rates of combustion exceeding 100 pounds per square foot of grate per hour, and, as just mentioned under "Heat Balance," the loss by CO due to the small air supply reached 9.28 per cent., whereas, with a properly drafted boiler, it should not exceed 3 per cent. of the heat in the coal fired at the maximum output of the boiler.

105. It is evident that to correct this trouble it would be necessary to increase the air inlet areas of the ashpan and the active grate area. The centre grate bearer, which is very wide, could be reduced in width to advantage, thus insuring a greater air supply. Such a grate is now used on E6s and H9s locomotive and is shown on Pennsylvania Railroad drawing 45427.

PERFORMANCE OF ENGINES.

General Conditions.

106. The general conditions affecting the engines and at the same time governing these tests are given in Table XII. The test designation includes the speed in r.p.m., the nominal cut-off in per cent. corresponding to the reverse lever notch, and the position of the throttle for each test. The letter "F" signifies that the locomotive was operated with a wide-open throttle.

107. The table includes the speed of the locomotive in revolutions per minute and equivalent miles per hour, the actual cut-off as obtained from the indicator cards, the steam pressure in boiler and branch pipe and the superheat in the branch pipe in degrees Fahr. The table is arranged in order according to speed and cut-off.

Superheat in Branch Pipe and Exhaust.

108. There is graphically shown in Fig. 34 the relation existing between the superheat in the branch pipe and the superheat in the exhaust pipe. The curve indicates a slow increase in the exhaust superheat as the superheat in the branch pipe increases from 100 to 165 degrees Fahr. Thus, the indication is that an increasing amount of heat is escaping at the exhaust and a decreasing amount of heat is being converted into work

Superheat in Branch Pipe and Indicated Horse-power.

109. The indicated horse-power is plotted in Fig. 35 with the superheat in the branch pipe. Above each of the points is given its respective nominal cut-off in per cent. of stroke. It is observed by the straight line that the degree of superheat increases directly with the power output of the locomotive. This fact has been shown in previous Bulletins describing tests on superheated steam locomotives. (See Bulletin No. 19, Fig. 40 and No. 21, Par 103.)

Indicator Diagrams.

110. Figs. 36 to 39, inclusive, present representative indicator diagrams for this locomotive. There is given with each diagram its respective test number, scale of pressure, speed in r.p.m. and miles per hour, the nominal cut-off and the indicated horse-power. The diagrams are designated as taken from the right or left side of the engine. For diagrams taken on the left side of the engine the steam chest diagrams are also given.

Least Back Pressure.

111. The relation between the least back pressure in pounds per square inch and the superheated steam in pounds per indicated horse-power hour is shown in Fig. 40. The tendency is for the least back pressure to decrease as the steam consumption per indicated horse-power hour increases. Further, these curves, being drawn through points of like cut-off, also indicate that at the same steam consumption per indicated horse-power hour the least back pressure increases with an increase of cut-off.

112. Fig. 41 shows, for both locomotives, the increase in the least back pressure as the indicated horse-power is increased. Up to 1000 i.h.p. there is no material difference between the two locomotives in this respect; the rate of increase in the least back pressure, however, is less rapid than at the higher powers, at which it is clear that the superheater locomotive develops a greater i.h.p. on a given back pressure, or that it requires less back pressure for a given i.h.p., due no doubt to the less amount of moisture in the exhaust with superheated steam.

Pressure Drop Between Boiler and Branch Pipe.

113. In Fig. 42 is shown the drop in pressure between throttle and branch pipe in pounds per square inch. The maximum drop is 11 pounds, occurring when the indicated horse-power reaches 1783.1 The curve shows the drop in pressure to increase with the power developed by the locomotive or with the increased volume of steam used.

Indicated Horse-power.

114. Table XIII is arranged according to the indicated horse-power; it includes the steam to the engines in pounds per hour, mean effective pressure, indicated horse-power, dry coal per indicated horse-power hour, superheated steam per indicated horse-power hour and the B.t.u. in the steam per indicated horse-power hour.

115. The indicated horse-power range is from 412.9 to 1829.9. Omitting tests of 30 minutes or less where the time of the test is too short for reliable coal records, the dry coal per indicated horse-power hour ranged between 2.2 and 3.9 pounds. The steam per i.h.p. hour likewise varies for different tests, ranging between 16.8 and 22.1 pounds per hour.

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LOCOMOTIVE:
TYPE 2-8-0
CLASS H8sb No. 387

PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

TEST DEPARTMENT

SHEET No. P-1181

Bulletin No. 10

Tests of a Class H8sb Locomotive. ALTOONA, PA. 1-7-1914

ENGINE TEST CONDITIONS.

Test No.	Test Designation	Duration of Test Minutes	Revolutions Per Minute	Speed in Miles Per Hour	Cut-off, Per cent of Stroke	Steam Pressure In Boiler Pounds Per sq.in.	Steam Pressure In Branch Pipe, Lbs. Per sq.in.	Superheat In Branch Pipe Degrees F
			198	199	272	217	220	230
3207	40-20-F	120	40	7.22	20.7	205.3	201.2	97.32
3210	40-30-F	120	40	7.19	31.9	205.3	202.0	130.64
3246	40-75-F	30	40	7.19	74.8	206.0	200.0	170.79
3247	40-88-F	15	40	7.19	88.0	206.0	200.7	171.32
3205	60-20-F	45	60	10.83	21.9	205.8	201.2	101.20
3206	60-20-F	105	60	10.83	22.0	205.9	201.7	108.92
3209	60-30-F	90	60	10.78	33.0	206.0	201.5	130.05
3227	60-35-F	90	60	10.78	35.3	206.0	201.2	134.96
3242	60-68-F	30	60	10.78	69.3	206.0	198.5	172.90
3245	60-77-F	30	60	10.78	74.8	203.3	194.7	165.71
3244	60-86-F	15	60	10.78	86.3	195.0	186.0	182.01
3201	80-20-F	120	80	14.44	23.8	205.8	202.4	125.59
3202	80-30-F	90	80	14.44	34.6	205.3	202.0	132.76
3203	80-40-F	30	80	14.44	42.1	206.0	201.5	144.98
3204	80-40-F	105	80	14.44	42.8	205.5	199.4	152.14
3238	80-55-F	30	80	14.38	51.8	206.0	200.0	179.32
3239	80-58-F	60	80	14.38	57.6	204.9	196.7	194.54
3241	80-63-F	60	80	14.38	63.4	204.7	195.9	210.25
3208	100-25-F	60	100	18.05	31.3	206.3	200.8	157.00
3211	100-25-F	30	100	17.97	30.9	205.8	201.0	157.41
3212	100-25-F	120	100	17.97	30.5	205.5	200.8	154.25
3213	100-40-F	30	100	17.97	42.6	203.3	197.3	155.46
3214	100-40-F	120	100	17.97	41.6	202.3	195.4	176.20
3215	100-45-F	120	100	17.97	45.4	204.5	196.2	179.67
3236	100-50-F	60	100	17.97	50.1	205.4	196.6	200.64
3237	100-55-F	60	100	17.97	52.6	203.4	194.6	185.38
3223	120-20-F	120	120	21.56	23.7	206.0	201.1	126.77
3221	120-30-F	120	120	21.56	33.9	205.9	199.8	155.56
3230	120-40-F	120	120	21.56	41.7	204.3	195.3	188.46
3216	120-50-F	60	120	21.56	50.5	186.1	176.3	192.52
3217	120-50-F	45	120	21.56	50.3	198.0	187.0	196.48
3225	140-25-F	90	140	25.16	29.5	205.6	199.4	176.34
3218	140-35-F	120	140	25.16	37.5	198.3	190.5	162.70
3220	140-40-F	60	140	25.16	41.5	204.9	196.0	168.88
3229	160-30-F	120	160	28.75	34.1	204.9	197.7	182.10
3222	160-35-F	60	160	28.75	37.9	203.3	194.7	167.47
3235	160-40-F	60	160	28.75	42.3	198.7	189.1	193.93
3228	170-20-F	120	170	30.50	22.4	205.8	200.3	145.70
3224	170-35-F	60	170	30.50	38.6	204.1	195.4	185.03

SHEET No. P-1181

Table XII.

ENGINE TEST CONDITIONS.

This table shows the pressure and superheat of the steam entering the steam chest for the various speeds and cut-offs at which tests were run.

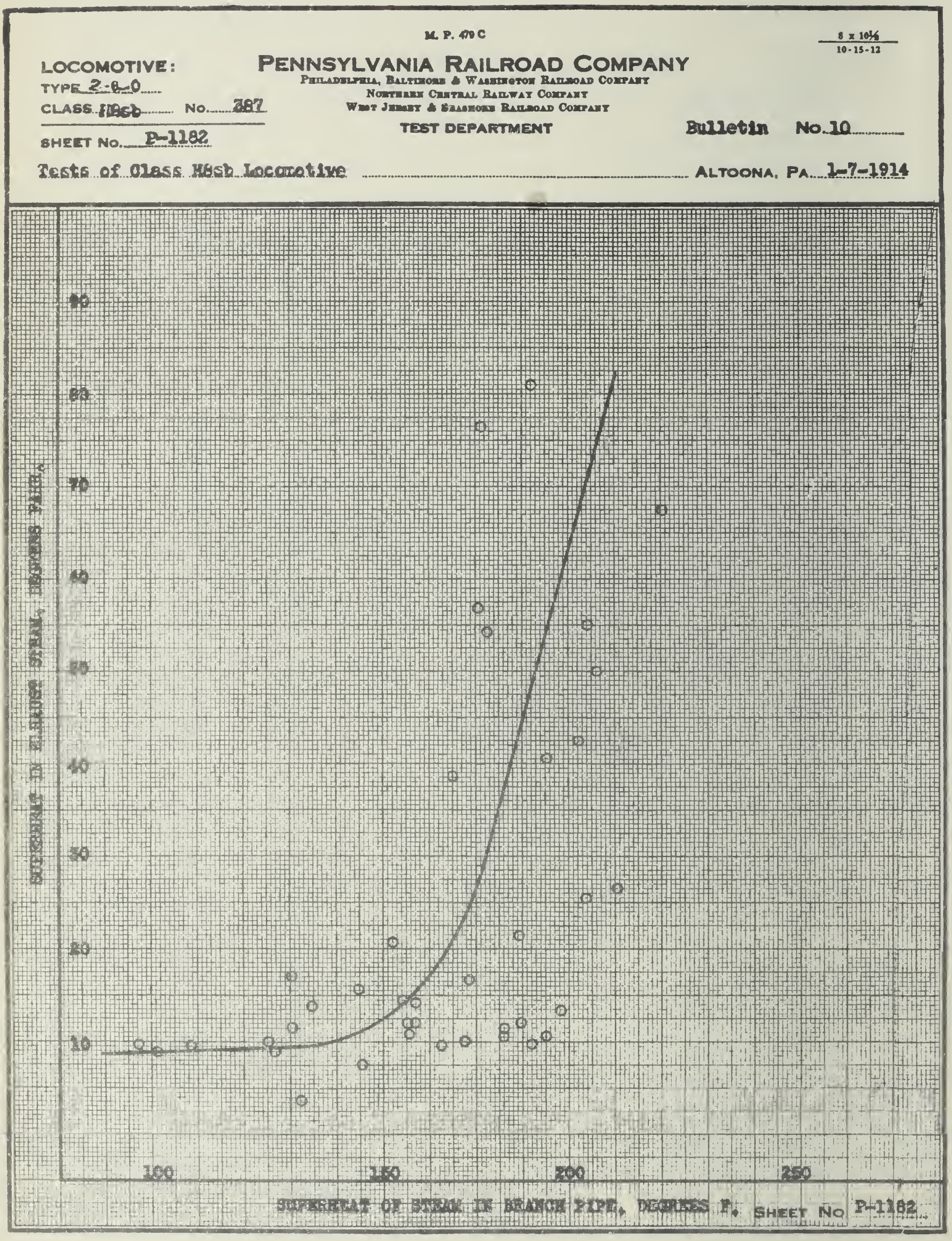

Fig. 34.

SUPERHEAT IN LIVE STEAM AND EXHAUST STEAM.

The exhaust superheat is small up to a superheat in the branch pipe of 165 degrees. Thereafter the superheat in the exhaust steam increases rapidly as the branch pipe superheat increases.

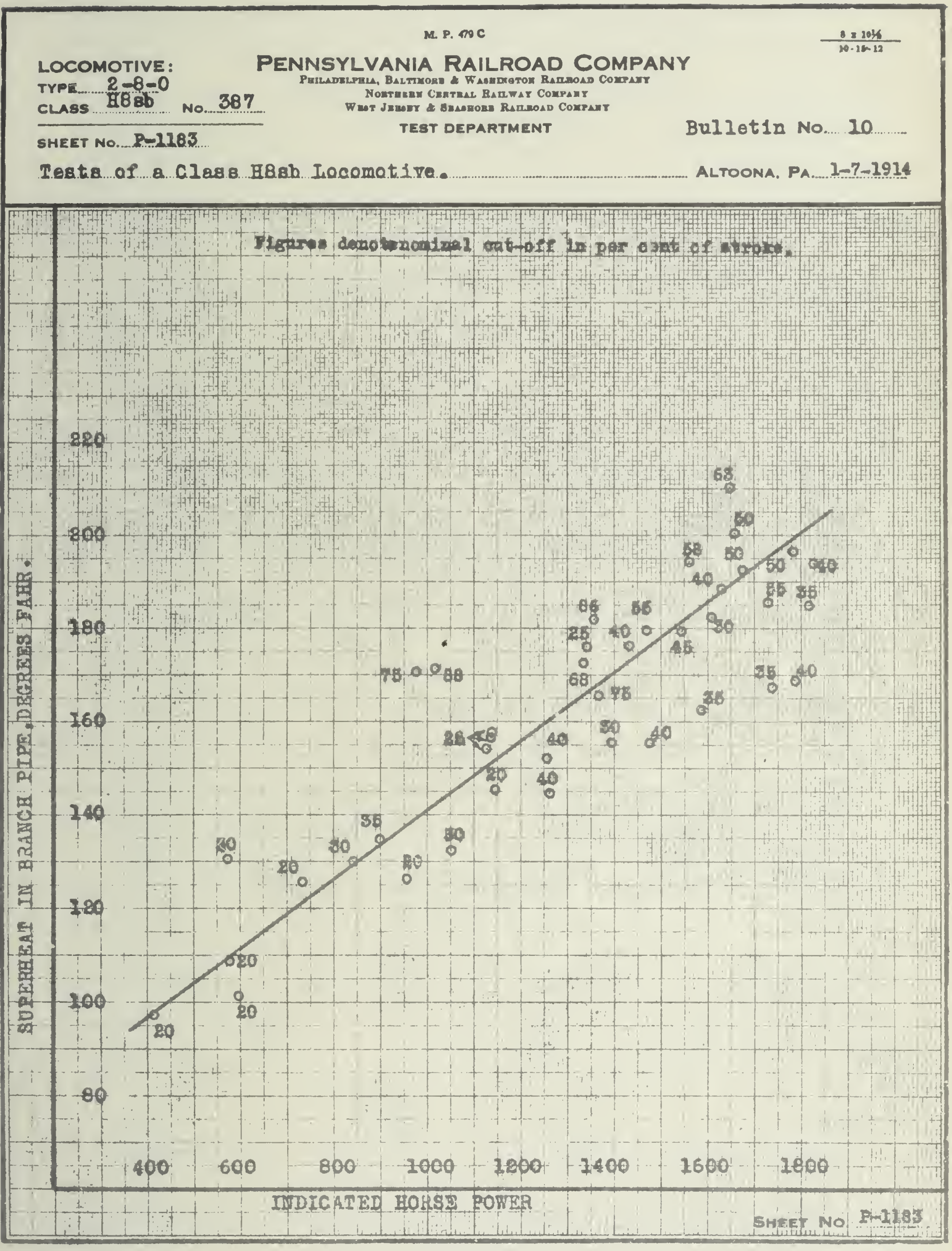

Fig. 35.

SUPERHEAT AND INDICATED HORSE-POWER.

The degree of superheat increases directly with the power output of the locomotive, due to the increased rate of burning coal.

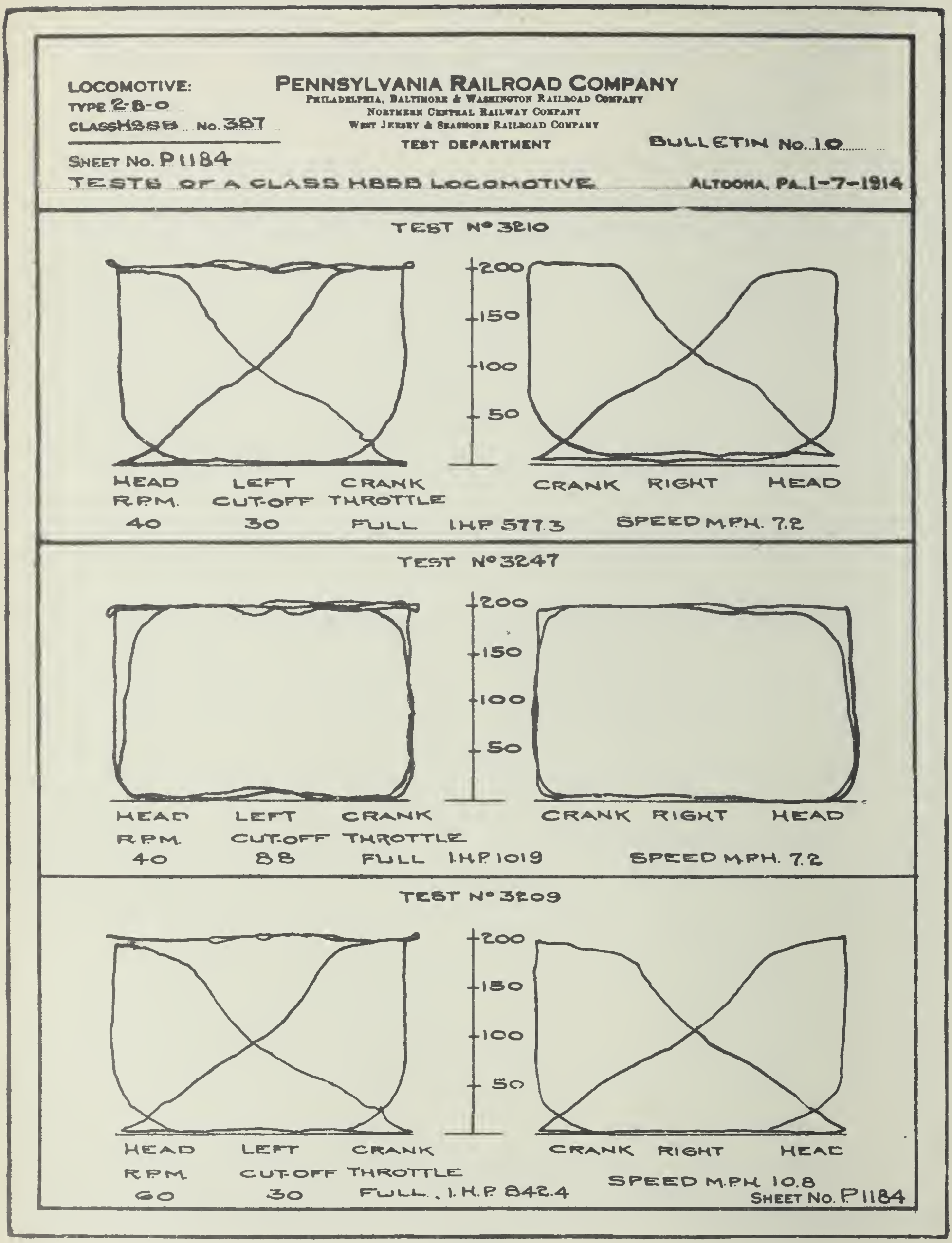

Fig. 36.

TYPICAL INDICATOR DIAGRAMS.

These diagrams are for speeds of 7 and 10 miles per hour.

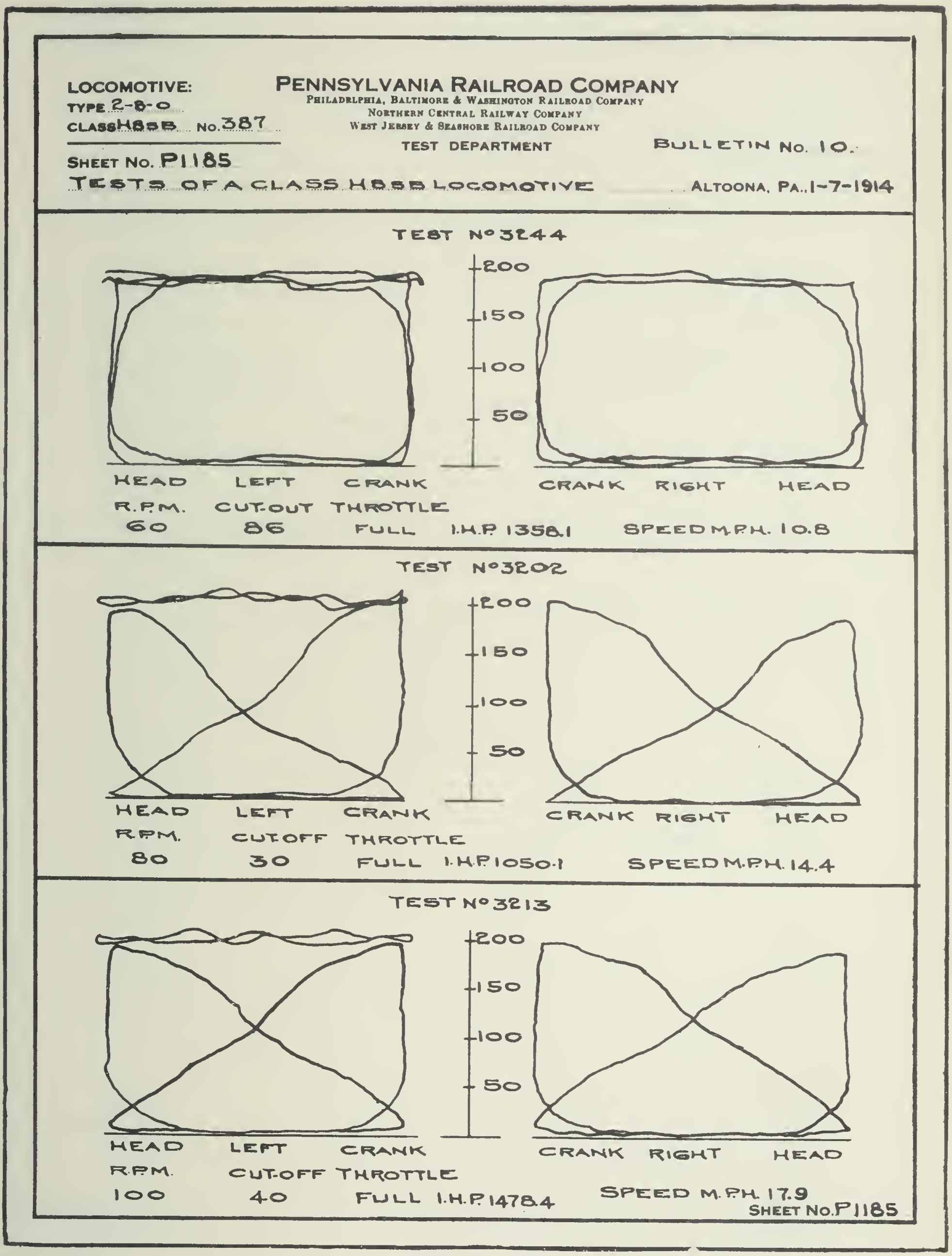

Fig. 37.

TYPICAL INDICATOR DIAGRAMS.

These diagrams are for speeds of 10, 14 and 18 miles per hour.

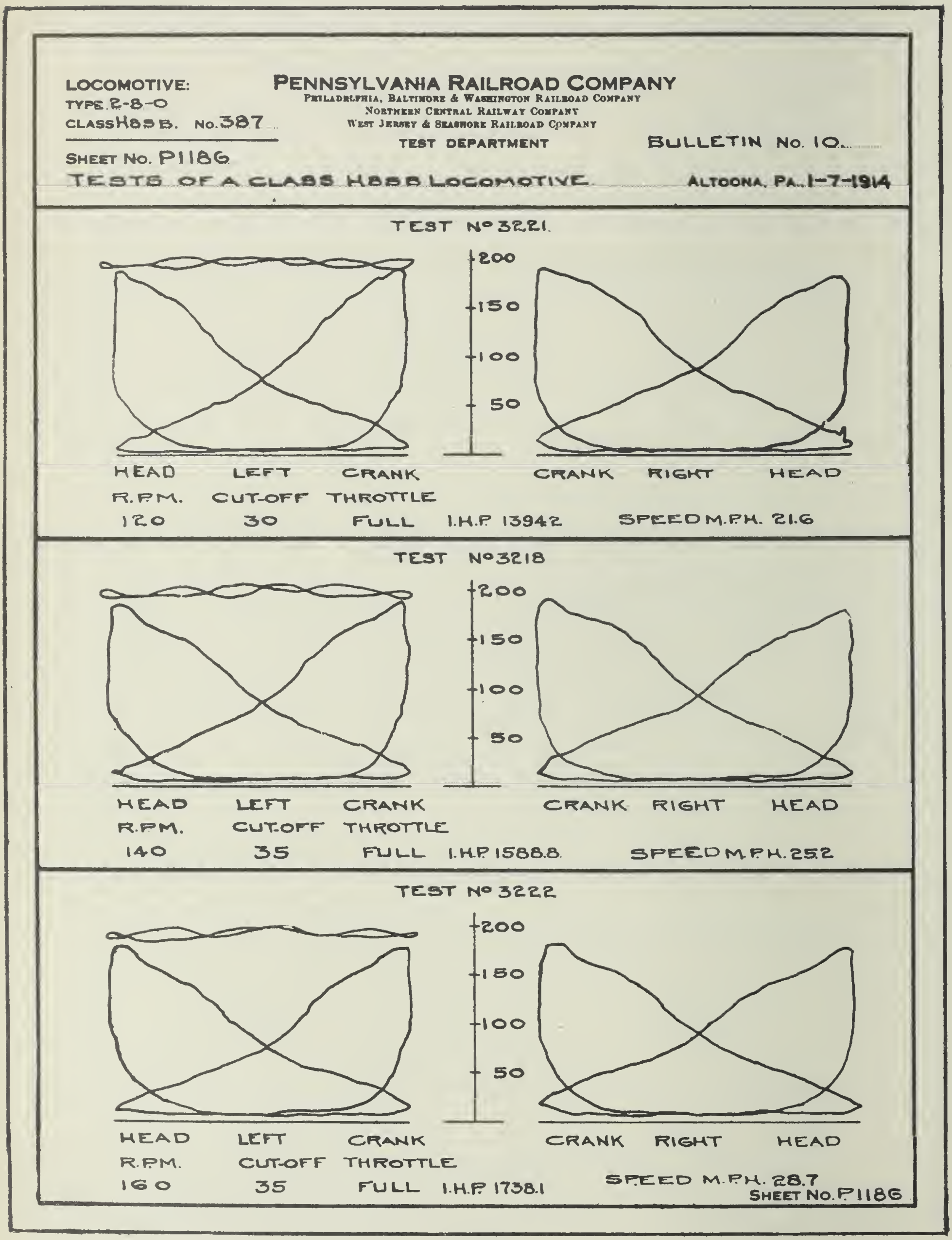

Fig. 38.

TYPICAL INDICATOR DIAGRAMS.

These diagrams are for speeds of 21, 25 and 28 miles per hour.

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CLASS H8-S-B No. 387

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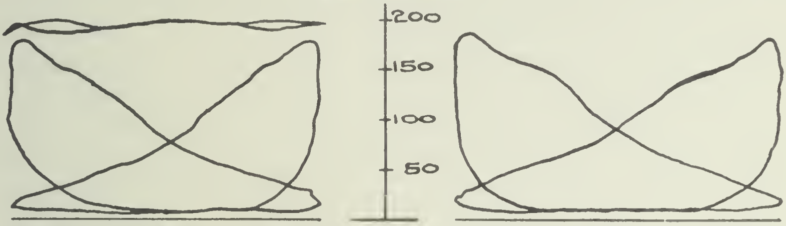
TEST DEPARTMENT

BULLETIN No 10

SHEET No. P1187

TESTS OF A CLASS H8-S-B LOCOMOTIVE — ALTOONA, PA., 1-7-1914

TEST No 3224



HEAD LEFT CRANK — CRANK RIGHT HEAD

R.P.M.	CUT-OFF	THROTTLE		
170	35	FULL	I.H.P. 1813.4	SPEED M.P.H. 30.5

SHEET No. P1187

Fig. 39.

TYPICAL INDICATOR DIAGRAMS.

These diagrams are for a speed of 30 miles per hour.

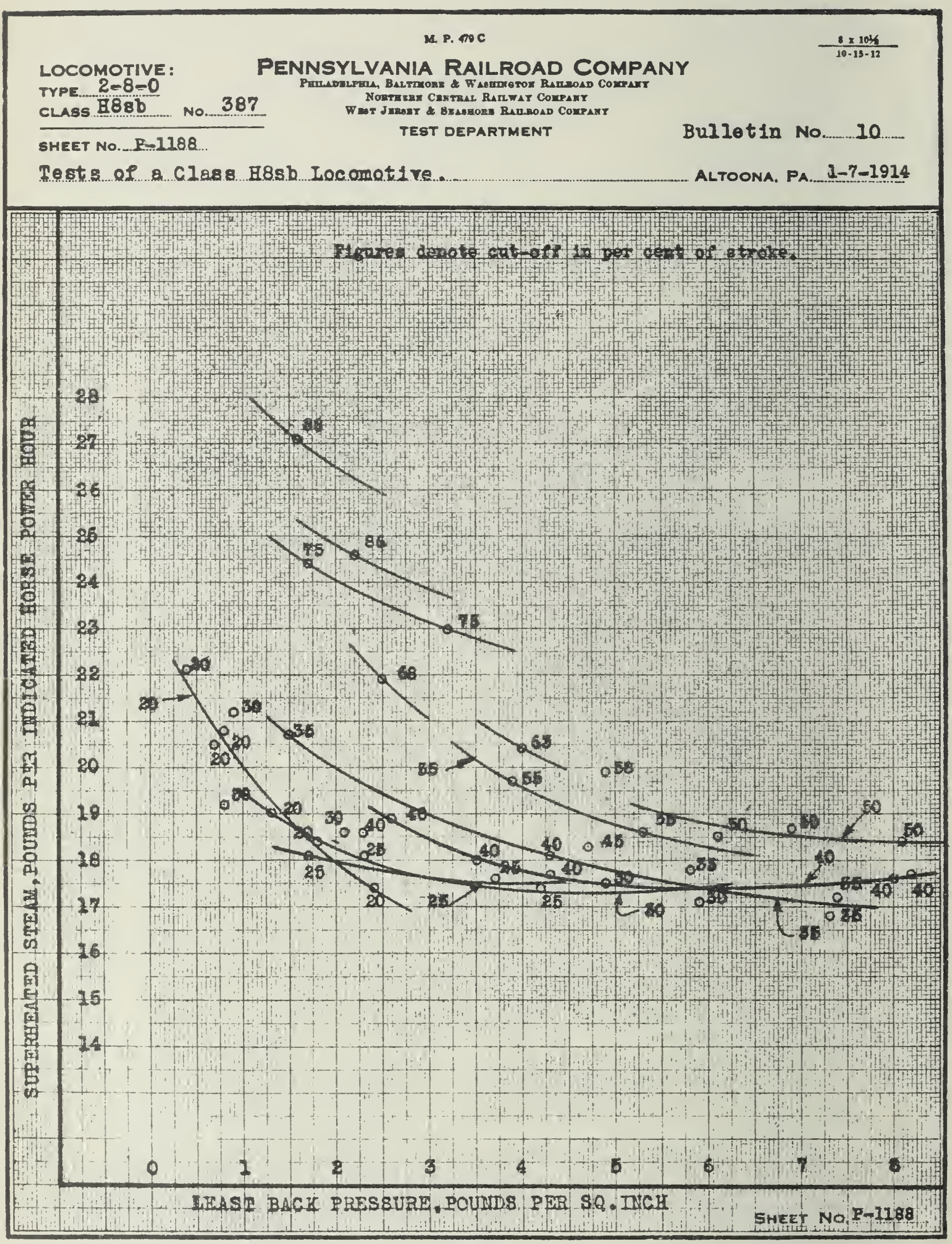


Fig. 40.

STEAM PER HORSE-POWER AND BACK PRESSURE.

The least back pressure decreases as the steam consumption per indicated horse-power hour increases, and at the same steam consumption per indicated horse-power hour the least back pressure increases with an increase of cut-off.

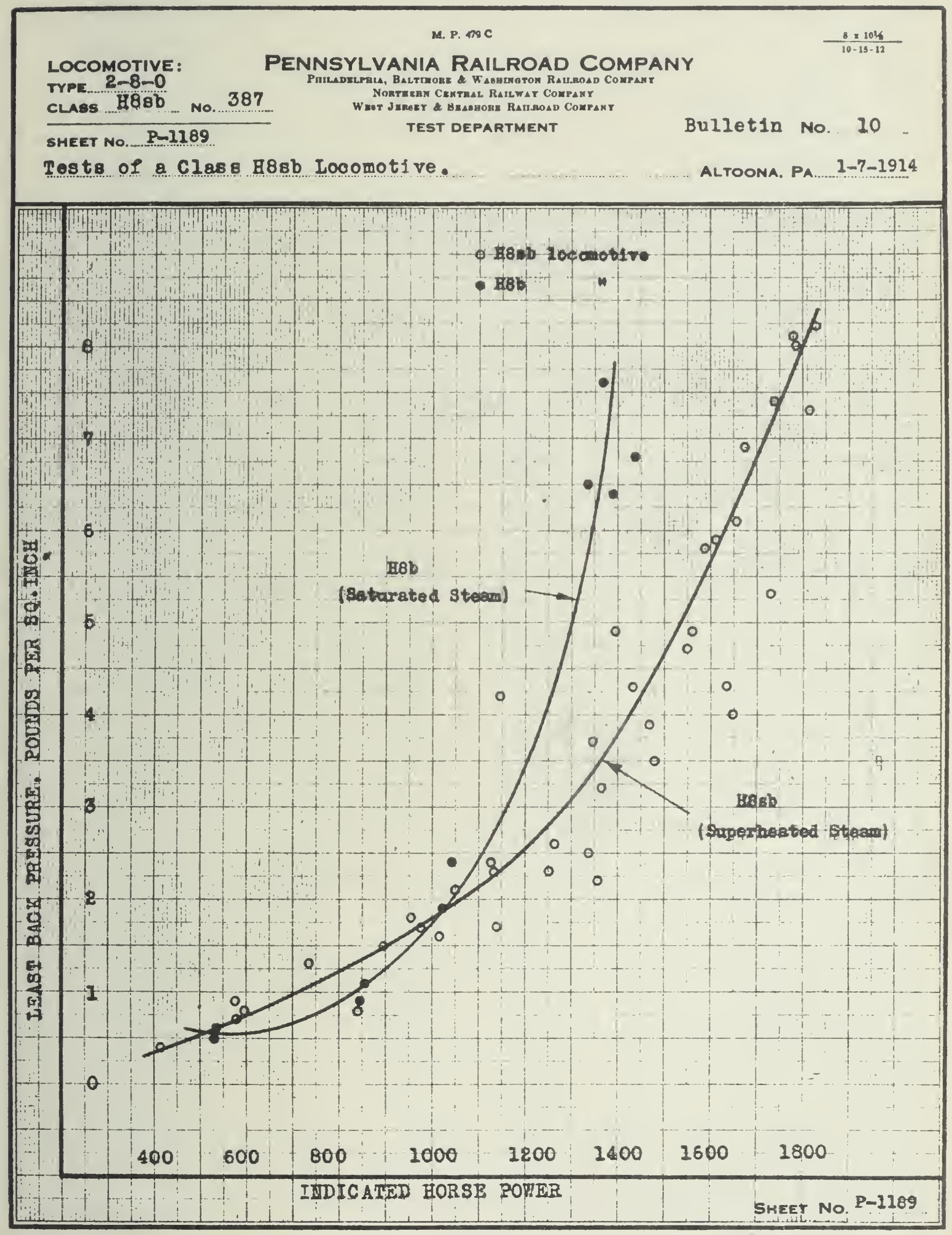


Fig. 41.

BACK PRESSURE AND HORSE-POWER.

The least back pressures for the H8b saturated steam locomotive are below those for the H8sb superheated steam locomotive at indicated horse-powers from 500 to 1040. Above this point the reverse is true.

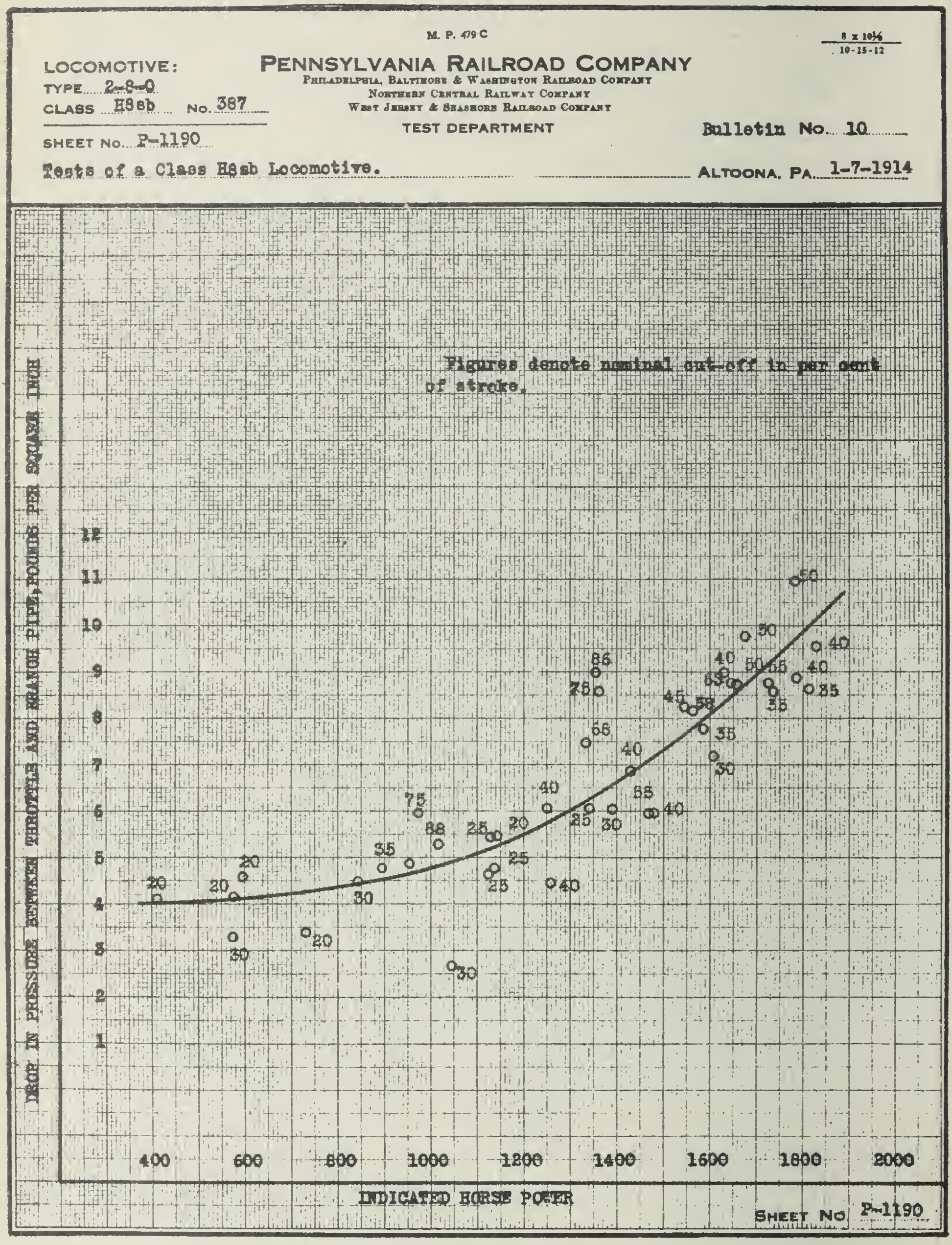


Fig. 42.

DROP IN PRESSURE THROUGH SUPERHEATER.

The curve shows that the drop in pressure increases with the indicated horse-power due to the increasing volume of steam used.

M. P. 479—A

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A 10½

LOCOMOTIVE:
TYPE 2-8-0
CLASS H8sb NO. 387

PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

TEST DEPARTMENT

Bulletin No. 10

SHEET NO. P-1191

Tests of a Class H8sb Locomotive. ALTOONA, PA. 1-7-1914

INDICATED HORSE POWER

Test No.	Test Designation	Duration of Test Mins.	Steam to Engines Pounds Per Hour	Mean Effective Pressure Pounds Per Square Inch	Indicated Horse power	Dry Coal per Indicated Horsepower Hour Pounds	Superheated Steam Per Indicated Horsepower Hour, Pounds	B.t.u. in Steam Per Indicated Horsepower Hour
			214		379	380	381	
3207	40-20-F	120	9116	75.37	412.9	2.4	22.1	27415
3210	40-30-F	120	12227	105.61	577.3	2.5	21.2	26692
3206	60-20-F	105	11865	70.66	579.5	2.4	20.5	25586
3205	60-20-F	45	12474	73.06	599.2	2.5	20.8	25971
3201	80-20-F	120	13927	67.14	733.5	2.5	19.0	23934
3209	60-30-F	90	16137	102.75	842.5	2.4	19.2	24029
3227	60-35-F	90	18633	109.68	899.4	2.6	20.7	25978
3223	120-20-F	120	17608	58.36	957.5	2.2	18.4	23076
3246	40-75-F	30	23892	178.83	977.9	3.6	24.4	31249
3247	40-88-F	15	27624	186.38	1019.0	5.9	27.1	34679
3202	80-30-F	90	19489	96.12	1050.1	2.4	18.6	23345
3212	100-25-F	120	19681	82.62	1129.0	2.2	17.4	22182
3208	100-25-F	60	20497	82.82	1131.9	2.2	18.1	23036
3211	100-25-F	30	20577	83.14	1138.5	2.6	18.1	22025
3228	170-20-F	120	19916	49.35	1147.6	2.6	17.4	21803
3204	80-40-F	105	23259	114.53	1252.4	2.6	18.6	23649
3203	80-40-F	35	23888	115.54	1262.9	2.3	18.9	24053
3242	60-68-F	30	29195	162.87	1336.6	4.4	21.9	27985
3225	140-25-F	90	23543	70.16	1341.6	2.4	17.6	22491
3244	60-86-F	15	33468	165.59	1358.1	5.0	24.6	31608
3245	60-75-F	30	31422	166.33	1364.3	5.7	23.0	29380
3221	120-30-F	120	24397	85.01	1394.2	2.5	17.5	22209
3214	100-40-F	120	25906	104.83	1432.7	2.9	18.8	23205
3238	80-55-F	30	28983	134.34	1469.0	4.0	19.7	25256
3213	100-40-F	30	26584	108.18	1478.4	2.7	18.0	22868
3215	100-45-F	120	28303	113.22	1547.5	3.1	18.3	23424
3239	80-58-F	60	31062	142.72	1560.7	3.9	19.9	25689
3218	140-35-F	120	28250	93.36	1588.8	3.2	17.8	22646
3229	160-30-F	120	27487	73.62	1610.4	2.6	17.1	22160
3230	120-40-F	120	28957	99.51	1632.2	2.9	17.7	22780
3241	80-63-F	60	33642	150.80	1649.4	3.1	20.4	26472
3236	100-50-F	60	30650	121.23	1657.0	3.0	18.5	23920
3216	120-50-F	60	31336	102.28	1677.5	3.4	18.7	24031
3237	100-55-F	60	32192	126.55	1729.6	3.4	18.6	23915
3222	160-35-F	60	29934	79.47	1738.1	2.9	17.2	21340
3217	120-50-F	45	32721	108.71	1783.1	3.5	18.4	23653
3220	140-40-F	60	31399	93.33	1786.3	3.0	17.6	22417
3224	170-35-F	60	30519	78.04	1813.4	2.7	16.8	21593
3235	160-40-F	60	32320	83.67	1829.9	3.1	17.7	22574

SHEET NO. P-1191

Table XIII.

INDICATED HORSE-POWER.

The maximum indicated horse-power was 1829.9, attained at a speed of 29 miles per hour with a cut-off of 40 per cent. The coal consumption does not exceed 3 pounds per indicated horse-power hour, except at cut-offs above 40 per cent., and the steam per horse-power hour ranges between 16.8 and 27.1 pounds.

116. Fig. 43 illustrates the increase in the heat in the steam per i.h.p. hour as the cut-off is increased, and also as the speed is decreased.

Coal and Steam Consumption Based on Indicated Horse-power.

117. The curve in Fig. 44 shows the dry coal fired in pounds per hour and the resulting indicated horse-power developed. It varies slightly from being a straight line between 400 and 1500 i.h.p. Above 1500 i.h.p. the coal consumption increases at a more rapid rate, and the indicated horse-power developed per 1000 pounds of coal fired per hour decreases. This is no doubt due to the large heat loss in the unburned fuel at the maximum rate of firing as is shown in Table X.

118. From the coal per hour curve is plotted another curve shown immediately below, and designated as the coal per indicated horse-power hour curve. From this curve it is observed that when the coal rate is 2.35 pounds per i.h.p. hour the indicated horse-power developed will reach 400. As the power of the locomotive is increased up to 1500 i.h.p. the coal rate will gradually increase to 2.67 pounds per i.h.p. hour, and at the maximum power output, or 1820 i.h.p., the rate is 3.04 pounds per i.h.p. hour.

119. In Fig. 45 the relation between the steam consumption in pounds per hour and the resulting indicated horse-power developed is represented by a straight line. This shows the indicated horse-power to increase directly with the steam consumption throughout the entire range of power developed by the locomotive. The steam per indicated horse-power hour curve on the same diagram is calculated from the steam per hour curve. It is presented to show what steam consumption may be expected from this superheated steam consolidation locomotive when operating it at indicated horse-powers from 400 to 1820.

120. The steam consumption is seen to rapidly drop as the power output is increased up to 1200 i.h.p., whereupon it falls off at a more gradual rate. This is characteristic of superheater locomotives, and is due to the increase in the degrees of superheat as

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LOCOMOTIVE:
TYPE 2-8-0
CLASS H8sb NO. 387

SHEET NO. P-1192

PENNSYLVANIA RAILROAD COMPANY
PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY
TEST DEPARTMENT

Bulletin No. 10

Tests of a Class H8sb Locomotive. ALTOONA, PA. 1-7-1914

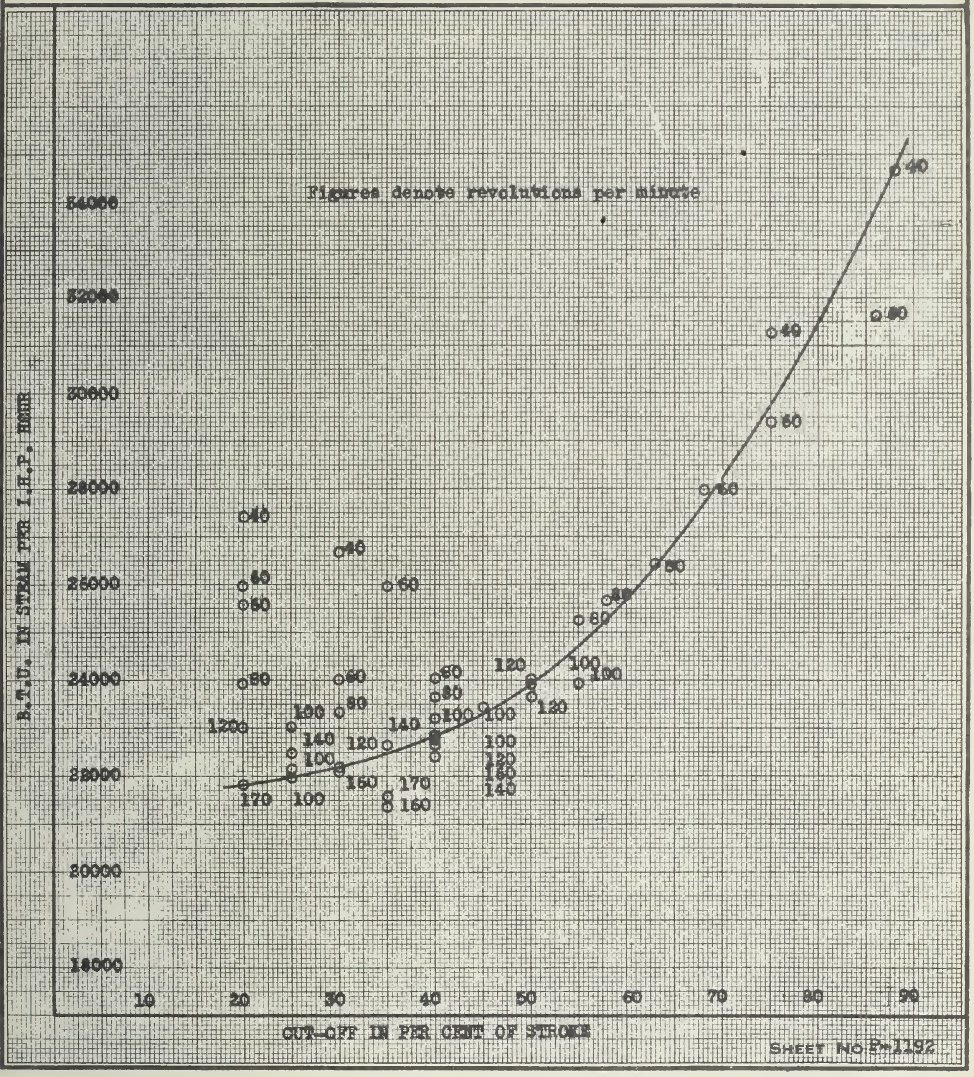

Fig. 43.

B. t. u. IN THE STEAM PER INDICATED HORSE-POWER HOUR AND CUT-OFF.

The heat supplied in the steam per indicated horse-power hour increases gradually up to a 50 per cent. cut-off, after which it increases with greater rapidity.

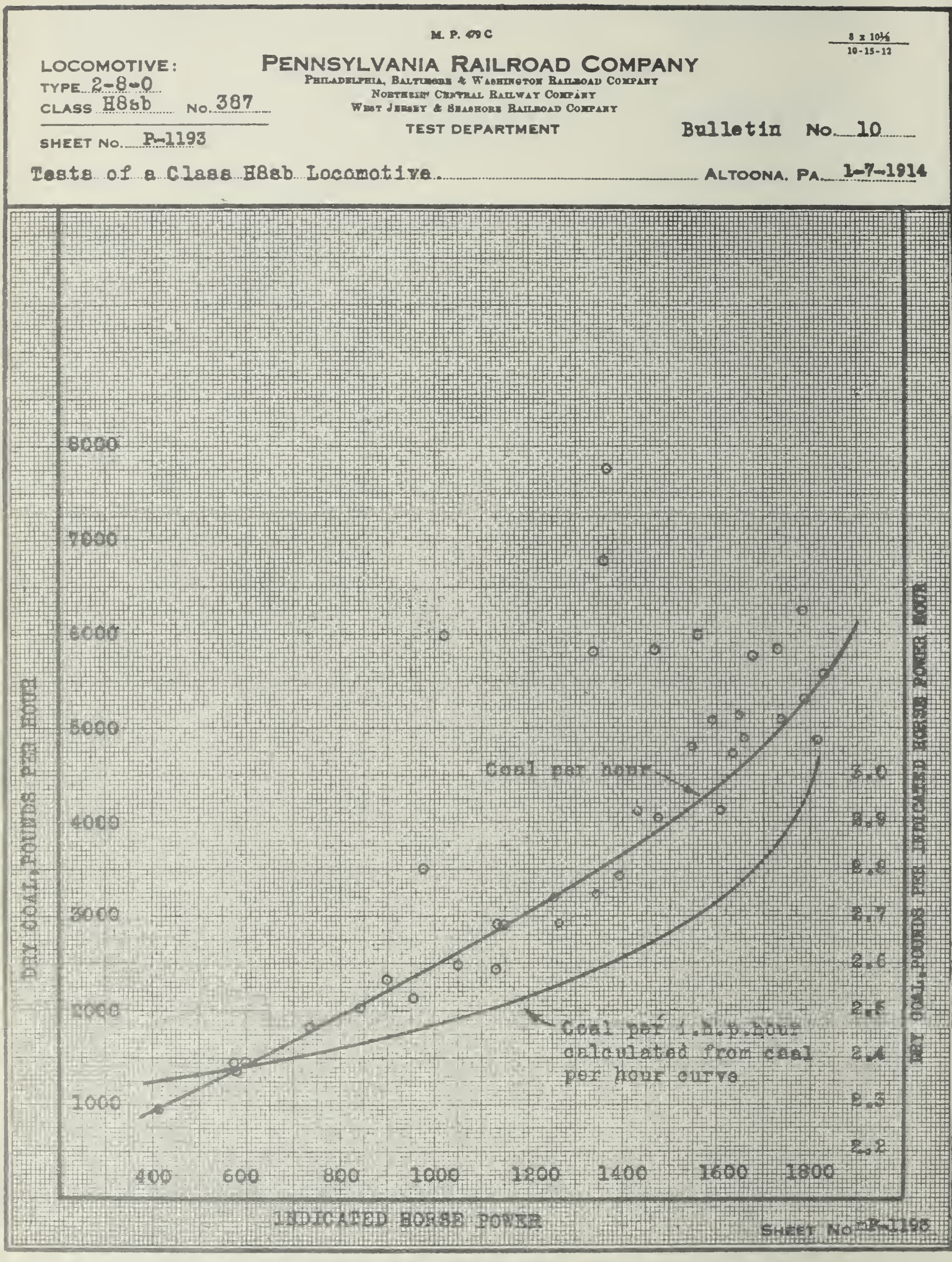

Fig. 44.

COAL PER HOUR AND HORSE-POWER.

The upper curve indicates the amount of coal fired per hour and the indicated horse-power produced by it. The lower curve is calculated from the curve above and represents the dry coal fired per indicated horse-power hour.

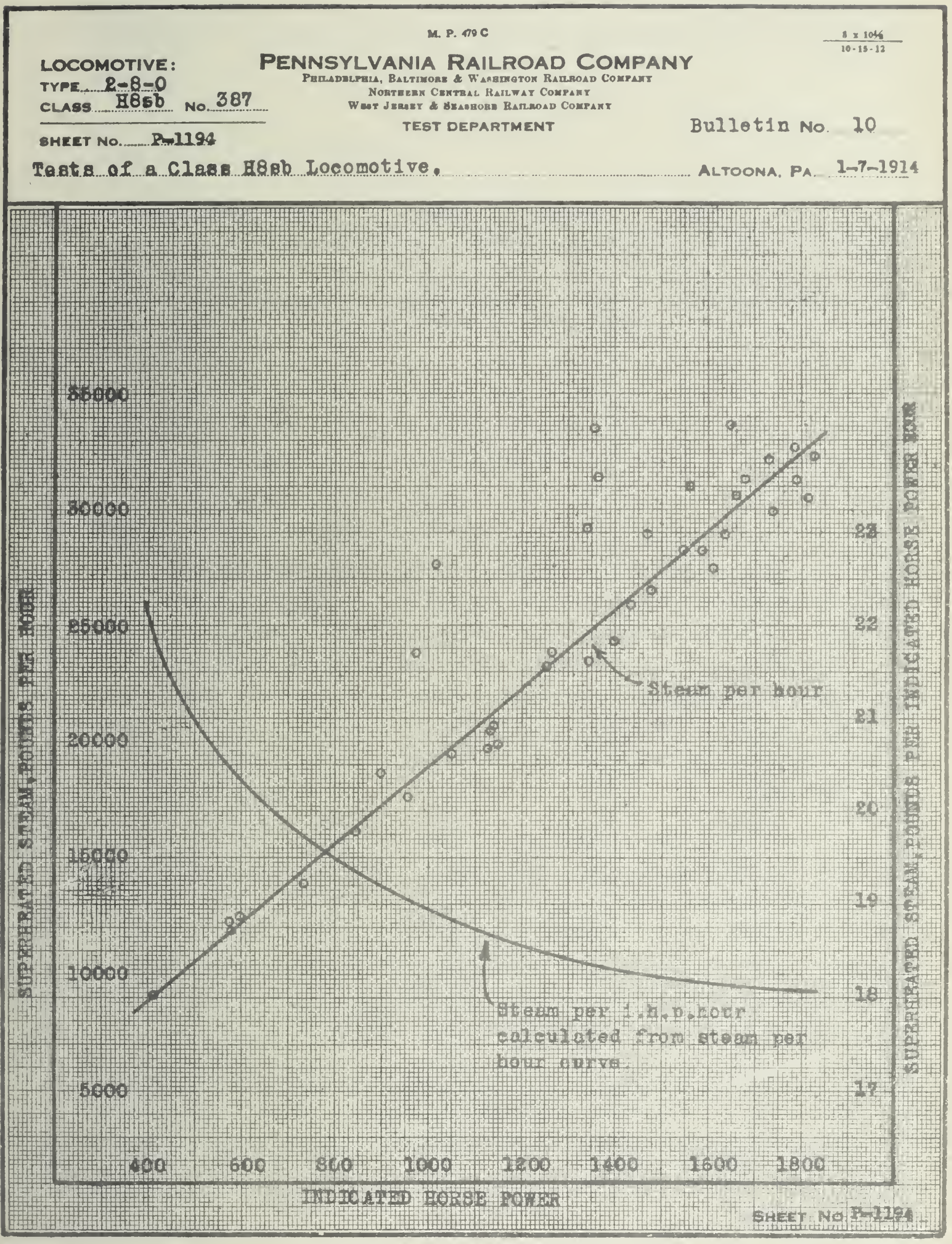

Fig. 45.

STEAM AND HORSE-POWER.

The straight line represents the steam supplied to the engines in pounds per hour and the horse-power developed from it. The curve below showing the steam per indicated horse-power hour is calculated from the straight line above.

the indicated horse-power increases. At 400 i.h.p, the steam consumption to be expected is approximately 22 pounds per i.h.p. hour, while at 1800 i.h.p., the steam consumption amounts to 18 pounds per i.h.p. hour.

Superheat and Water Rate.

121. There is given in Table XIV, the draft in front of diaphragm in inches of water, the indicated horse-power, B.t.u. in the steam per indicated horse-power hour, superheated steam per indicated horse-power hour in pounds, dry coal per indicated horse-power hour in pounds and the superheat in the branch pipe in degrees Fahr. The table is arranged according to the increase in the branch pipe superheat, and is presented to show just what takes place throughout the range of superheat. It is seen that the superheat increases with the draft and the indicated horse-power (Fig. 35).

122. A comparison of the fuel consumption of an H8b saturated steam locomotive, an H6b saturated steam locomotive and the H8sb superheated steam locomotive, No. 387, is given in Fig. 46. The H8b and H8sb locomotives are similar with the exception that the latter has a Schmidt type superheater and larger cylinders. The H6b locomotive has a smaller grate area and heating surface than either of the H8 locomotives and it did not have a brick arch. Its cylinders are two inches smaller in diameter.

123. The remarkable uniformity in the coal consumption per indicated horse-power hour for the H8sb is observed at indicated horse-powers ranging from 400 to 1300 i.h.p. The coal consumption per i.h.p. hour is approximately 2.5 pounds up to 1300 i.h.p. and from there on it increases to 3.5 pounds per i.h.p. hour at 1800 i.h.p. The exceptional (higher) results were obtained in tests of 30 minutes or less duration (see Par. 115).

124. The absence of an arch in the H6b locomotive no doubt accounts for the small difference in coal consumption between it and the H8b saturated steam locomotive at corresponding indicated horse-powers.

M. P. 479—A

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LOCOMOTIVE:
TYPE 2-8-0
CLASS H8sb No. 387

PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

TEST DEPARTMENT

Bulletin No. 10

SHEET No. P-1195

Tests of a Class H8sb Locomotive.

ALTOONA, PA. 1-7-1914

SUPERHEAT AND WATER RATE.

Test No.	Test Designation	Draft Front of Diaphragm Inches of Water	Indicated Horse power	B.t.u. in Steam Per Indicated Horsepower Hour	Superheated Steam Per Indicated Horsepower Hour, Pounds	Dry Coal Per Indicated Horsepower Hour, pounds	Superheat in Branch Pipe
		222	379		381	380	230
3207	40-20-F	0.9	412.1	27415	22.1	2.4	97.32
3205	60-20-F	1.3	599.2	25971	20.8	2.5	101.20
3206	60-20-F	1.1	579.5	25586	20.5	2.4	108.92
3201	80-20-F	1.7	733.5	23934	19.0	2.5	125.59
3223	120-20-F	2.0	957.5	23076	18.4	2.2	126.77
3209	60-30-F	2.0	842.5	24029	19.2	2.4	130.05
3210	40-30-F	1.5	577.3	26692	21.2	2.5	130.64
3202	80-30-F	2.4	1050.1	23345	18.6	2.4	132.76
3227	60-35-F	2.3	899.4	25978	20.7	2.6	134.96
3203	80-40-F	3.0	1262.9	24053	18.9	2.3	144.98
3228	170-20-F	2.9	1147.6	21803	17.4	2.6	145.70
3204	80-40-F	3.2	1252.4	23649	18.6	2.6	152.14
3212	100-25-F	2.3	1129.0	22182	17.4	2.2	154.25
3213	100-40-F	4.5	1478.4	22868	18.0	2.7	155.46
3221	120-30-F	3.7	1394.2	22209	17.5	2.5	155.56
3208	100-25-F	2.4	1131.9	23036	18.1	2.2	157.00
3211	100-25-F	2.6	1138.5	22025	18.1	2.6	157.41
3218	140-35-F	5.5	1588.8	22646	17.8	3.2	162.70
3245	60-75-F	7.8	1364.3	29380	23.0	5.7	165.71
3222	160-35-F	5.9	1738.1	21340	17.2	2.9	167.47
3220	140-40-F	5.9	1786.3	22417	17.6	3.0	168.88
3246	40-75-F	5.4	977.9	31249	24.4	3.6	170.79
3247	40-88-F	6.2	1019.0	34679	27.1	5.9	171.32
3242	60-68-F	6.0	1336.1	27985	21.9	4.4	172.90
3214	100-40-F	4.0	1432.7	23205	18.1	2.9	176.20
3225	140-25-F	3.2	1341.6	22491	17.6	2.4	176.34
3238	80-55-F	5.4	1469.0	25256	19.7	4.0	179.32
3215	100-45-F	5.1	1547.5	23424	18.3	3.1	179.67
3244	60-86-F	8.1	1358.1	31608	24.6	5.0	182.01
3229	160-30-F	4.6	1610.4	22160	17.1	2.6	182.10
3224	170-35-F	5.8	1813.4	21593	16.8	2.7	185.03
3237	100-55-F	6.2	1729.6	23915	18.6	3.4	185.38
3230	120-40-F	5.1	1632.2	22780	17.7	2.9	188.46
3216	120-50-F	6.3	1677.5	24031	18.7	3.4	192.52
3235	160-40-F	6.4	1829.9	22574	17.7	3.1	193.93
3239	80-58-F	6.1	1560.7	25689	19.9	3.9	194.54
3217	120-50-F	6.6	1783.1	23653	18.4	3.5	196.48
3236	100-50-F	5.8	1657.0	23920	18.5	3.0	200.64
3241	80-63-F	6.7	1649.4	26472	20.4	3.1	210.25

SHEET No. P-1195

Table XIV.

SUPERHEAT AND WATER RATE.

A table arranged to show the influence of the superheat upon the water and coal rates. Conditions such as cut-off and power developed obscure the effect of superheat.

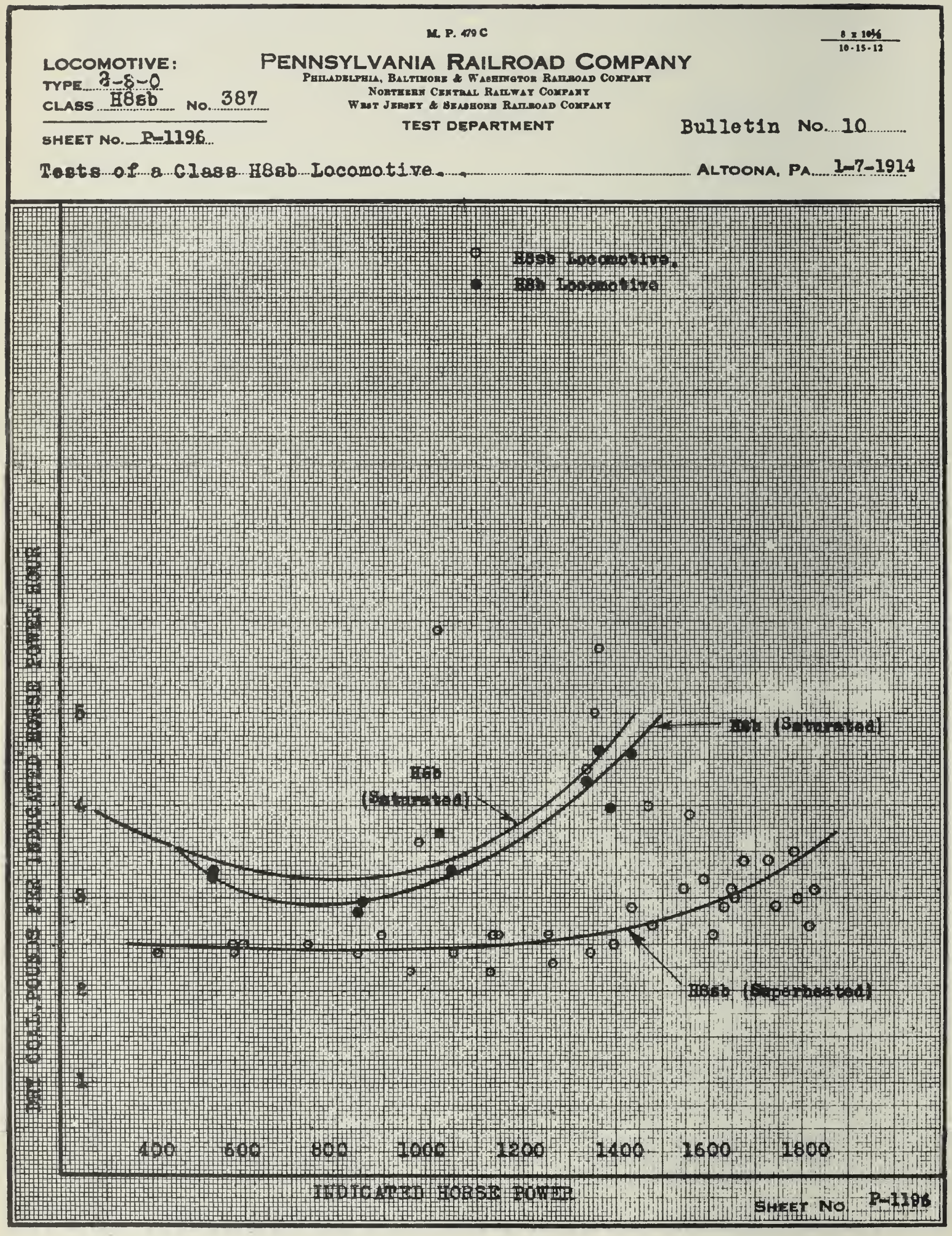

Fig. 46.

COAL PER INDICATED HORSE-POWER HOUR.

The application of a superheater to the H8b saturated steam locomotive, and the enlargement of its cylinders from 24 to 25 inches in diameter, results in a very substantial saving in coal.

125. Comparing the curves for the H8b and H8sb locomotives, it is at once apparent that the application of a superheater to the H8b locomotive together with an increase in cylinder diameter has materially increased the economy in coal for this class of locomotives. At 500 i.h.p. the saving is approximately 24 per cent., while at 1500 i.h.p. the saving is 45 per cent. There is observed a very uniform rate of burning coal up to this point. Above 1500 i.h.p. the rate of combustion for the H8sb locomotive increases materially. Under the conditions it is at least unusual for the rate of combustion to exceed $3\frac{1}{2}$ pounds per i.h.p. hour up to 1800 i.h.p., and with the proper air supply this should not exceed 3 pounds.

126. There is shown in Fig. 47 the comparative performance of the H6b, H8b and H8sb locomotives from the standpoint of steam consumption per i.h.p. hour.

127. The steam consumption of the superheated steam H8sb locomotive decreases as the power output increases from 400 to 1400 i.h.p. From this point the increase, if any, is very slight up to 1800 i.h.p., or until the capacity of the boiler is reached. At 400 i.h.p. the steam consumption is 22 pounds per i.h.p. hour. The minimum consumption, or 17.6 pounds per i.h.p. hour, is obtained at 1400 i.h.p. and at the maximum power output the steam consumption increased to 18.8 pounds per i.h.p. hour.

128. The saving in water thus effected between the H8b saturated steam and the H8sb superheated steam locomotives is 26.3 per cent. at 500 i.h.p. and 35 per cent. at 1500 i.h.p., based upon the steam consumption per indicated horse-power hour.

129. The H6b saturated steam locomotive is shown to be more economical in steam than the H8b saturated steam locomotive more particularly at the lower corresponding indicated horse-powers. This probably is due to the fact that the H6b locomotive has cylinders two inches smaller in diameter than those on the H8b locomotive. The size of the H6b cylinders is 22 inches in diameter with a 28-inch stroke.

130. The economy in steam of the H8sb superheater locomotive as compared with the H8b locomotive using saturated steam is due primarily to the superheater, and the fact that the cylinders were increased in diameter from 24 inches to 25 inches for the use of superheated steam.

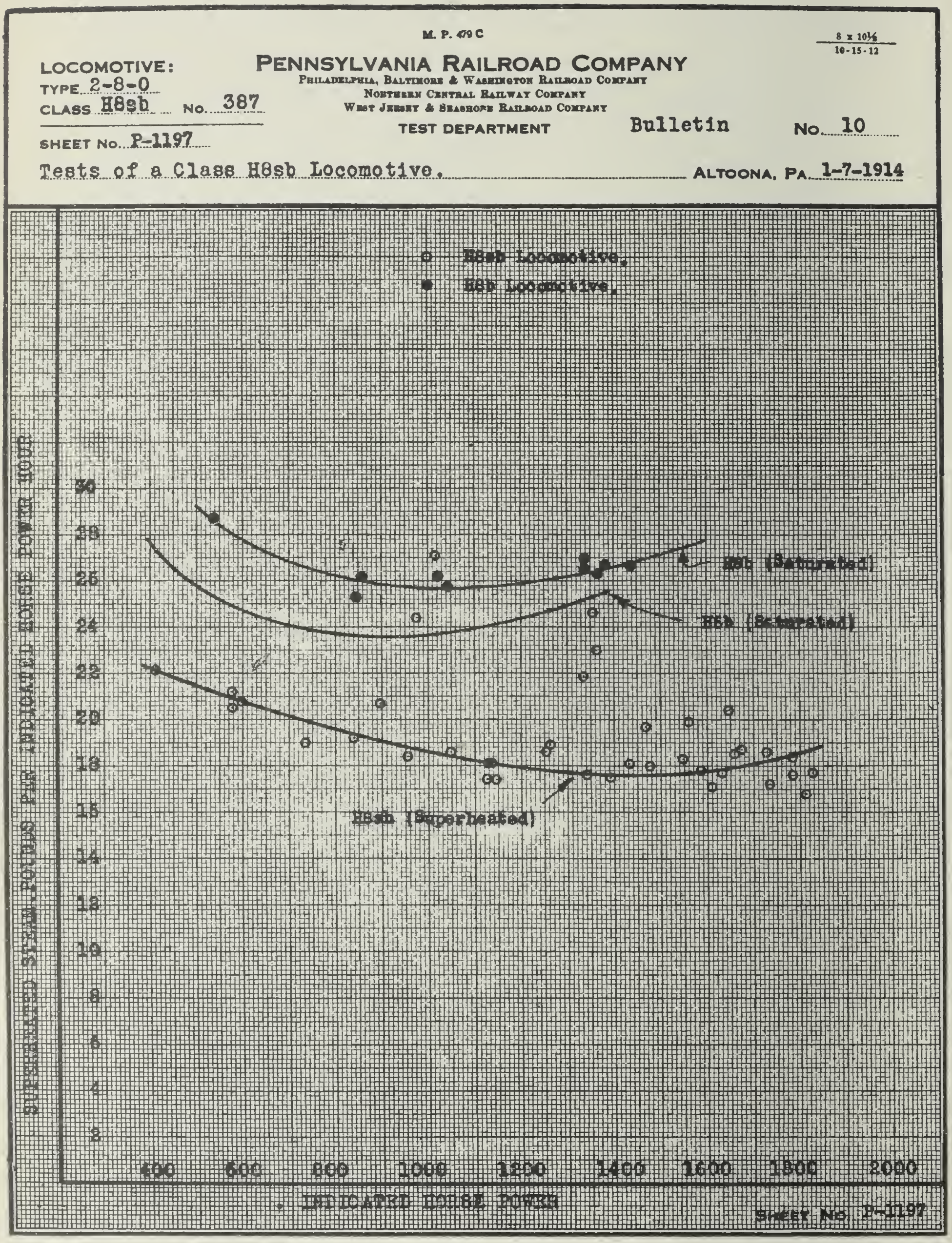

Fig. 47.

STEAM PER INDICATED HORSE-POWER.

A remarkable saving in steam is apparent when comparing the curve for the H8sb superheater with the curve representing the performance of the H8b saturated steam locomotive.

LOCOMOTIVE PERFORMANCE.

Dynamometer Records.

131. We will now consider the test results for the locomotive as a whole, or the drawbar pull, the rates of coal and water consumption per drawbar horse-power, and the output of the locomotive in drawbar horse-power at the various speeds.

132. Comparison will be made with the class H6b, the typical freight locomotive, which is the immediate predecessor of the H8 and H9 classes.

Drawbar Horse-power.

133. Table XV gives the drawbar pull obtained during each of the tests, the dynamometer or drawbar horse-power, the dry coal per dynamometer horse-power hour, superheated steam per dynamometer horse-power hour, the B.t.u. in the steam per drawbar horse-power hour and the thermal efficiency of the locomotive.

134. The drawbar pull ranged from 9723 pounds at 30.5 m.p.h. with a 20 per cent. cut-off to 49,872 pounds at 7.2 m.p.h. and 88 per cent. cut-off. This pull of 49,872 pounds is 3582 pounds above the rated tractive force, which is arbitrarily based upon 80 per cent. of the boiler pressure as mean effective pressure and represents the maximum pull which can safely be counted upon under average conditions. The locomotive was operated with a wide-open throttle during all of the tests.

135. The dynamometer horse-power was 314.2 at 7.2 m.p.h. with a 20 per cent. cut-off and 1587.8 at 17.97 m.p.h. and a 55 per cent. cut-off.

136. The coal consumption ranged between 2.6 and 4.3 pounds per d.h.p. hour and the steam consumption from 20.2 pounds to 29 pounds per d.h.p. hour. In discussing the coal rates, we will omit reference to tests of 30 minutes or less, as they were run primarily to obtain a pull speed curve and the time of the test was too short to make accurate measurements of coal used.

137. The thermal efficiency of the locomotive ranged from 6.7 per cent. to 2.9 per cent. The highest thermal efficiency obtained from the H6b saturated steam locomotive was 5.22 per cent., while the thermal efficiency of the H8b locomotive reached 5.47 per cent.

138. The limit of power is shown in Fig. 15. Up to a rate of firing of about 100 pounds per square foot of grate per hour, there is a corresponding increase in dynamometer horse-power. If coal is fired at rates above 100 pounds, there may even be a decrease in power. Sixteen hundred dynamometer horse-power is then about the maximum possible.

139. The steam consumption per indicated horse-power hour at each speed throughout the range of cut-off is shown in Fig. 48. It is observed that the most economical cut-off is at 30 per cent. of the stroke and that an economical range of cut-off is found between 20 and 40 per cent. of the stroke. At each speed the steam consumption per indicated horse-power hour decreases slightly with an increase in the cut-off until a 30 per cent. cut-off is reached, beyond this cut-off it increases rapidly at slow speeds down to and including 60 r.p.m (10.8 m.p.h.). The steam consumption per indicated horse-power is high at cut-offs above 50 per cent. The most economical cut-off, however, as will be seen, may be utilized only when the locomotive can be worked well within its maximum as to boiler capacity and cylinder power, which maximum, as shown by Fig. 48, requires a cut-off between 88 per cent. in full gear and seldom, if ever, less than the 42 per cent. necessary at 30 m.p.h., about the maximum speed for this class of locomotive.

140. The indicated horse-power at like cut-offs with an increase in speed and also at like speeds with an increase of cut-off is shown by Fig. 49. At speeds up to 80 r.p.m. (14.4 m.p.h.) the increase in power following an increase in cut-off is less rapid than at higher speeds, in other words, for a given increase in cut-off at any two speeds there is approximately the same increase in mean effective pressure, making the increase in power nearly proportional to the speed.

Maximum Power of Locomotive.

141. The maximum drawbar pull of the H8sb locomotive, at any given speed, as limited by the capacity of the boiler, was attained when approximately 33,700 pounds of water was evaporated, and furnished to the cylinders per hour.

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LOCOMOTIVE:
TYPE 2-8-0
CLASS H8sb No. 387

PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

TEST DEPARTMENT

Bulletin No. 10

SHEET NO. P-1201

Tests of a Class H8sb Locomotive.

ALTOONA, PA. 1-7-1914

DRAWBAR HORSEPOWER

Test No.	Test Designation	Duration of Test Mins.	Drawbar Pull in Pounds	Dynamometer or Drawbar Horsepower	Dry Coal Per Dynamometer Horsepower Hour	Superheated Steam Per Dynamometer Horsepower Hour	B.t.u. in Steam Per Drawbar Horsepower Hour	Thermal Efficiency Of Locom. Per cent
			265	383	384	385		399
3207	40-20-F	120	16331	314.2	3.1	29.0	35953.4	5.6
3206	60-20-F	105	15653	452.9	3.0	26.3	32809.2	5.8
3205	60-20-F	45	16221	468.3	3.1	26.0	33229.3	5.6
3310	40-30-F	120	24524	472.0	3.1	25.9	32652.8	5.6
3201	80-20-F	120	14050	540.9	3.4	25.8	32455.1	5.1
3209	60-30-F	90	23480	677.9	3.0	23.8	29859.6	5.8
3227	60-35-F	90	26323	760.0	3.1	24.5	30717.5	6.2
3223	120-20-F	120	13348	770.8	2.8	22.8	27781.4	6.6
3228	170-20-F	120	9723	795.4	3.7	25.0	31455.8	5.2
3202	80-30-F	90	22695	873.7	2.9	22.3	28171.7	6.1
3246	40-75-F	30	48855	878.8	4.0	27.2	34769.6	4.5
3211	100-25-F	30	18630	896.5	3.3	23.0	29081.5	5.3
3208	100-25-F	60	18670	898.4	2.7	22.8	29023.6	6.4
3212	100-25-F	120	19542	940.4	2.6	20.9	26631.6	6.7
3247	40-88-F	15	49872	955.7	6.3	28.9	36974.4	2.9
3203	80-40-F	30	27562	1061.0	2.8	22.5	28619.2	6.3
3225	140-25-F	90	15884	1070.1	3.0	22.0	28196.8	6.3
3204	80-40-F	105	28053	1079.9	3.0	21.5	27425.3	5.9
3221	120-30-F	120	19779	1142.1	3.0	21.4	27111.6	6.1
3242	60-68-F	30	41815	1202.9	4.8	24.3	31084.0	3.7
3245	60-75-F	30	42865	1232.2	6.3	25.5	32529.4	2.9
3213	100-40-F	30	25788	1240.9	3.3	21.4	27244.5	5.3
3214	100-40-F	120	25957	1249.1	3.3	20.7	26566.6	5.6
3244	60-86-F	15	44284	1273.0	5.3	26.3	33721.2	3.4
3229	160-30-F	120	16628	1280.2	3.2	21.5	27819.4	5.9
3238	80-55-F	30	33847	1297.3	4.5	22.3	28598.4	4.2
3218	140-35-F	120	20131	1356.2	3.8	20.8	26530.0	4.9
3215	100-45-F	120	28373	1365.3	3.5	20.7	26549.6	5.2
3239	80-58-F	60	36898	1414.2	4.3	22.0	28340.0	4.5
3230	120-40-F	120	24645	1423.1	3.3	20.4	26127.0	5.8
3222	160-35-F	60	18515	1425.5	3.6	21.0	26721.6	5.1
3241	80-63-F	60	37502	1437.4	3.6	23.4	30438.9	5.3
3224	170-35-F	60	17835	1459.0	3.3	20.9	26846.3	5.7
3216	120-50-F	60	25758	1487.4	3.9	21.1	27267.1	4.7
3236	100-50-F	60	31518	1516.6	3.2	20.2	26133.7	5.9
3235	160-40-F	60	19924	1534.0	3.6	21.1	27072.1	5.3
3220	140-40-F	60	22791	1535.4	3.5	20.5	26080.3	5.3
3217	120-50-F	45	27184	1569.7	4.0	20.9	26868.0	4.6
3237	100-55-F	60	33141	1587.8	3.7	20.3	26051.2	5.2

SHEET NO. P-1201

Table XV.

DRAWBAR HORSE-POWER.

The drawbar pull developed ranges between 9723 pounds at 30.5 miles per hour with a 20 per cent. cut-off, and 49,872 pounds at 7.2 miles per hour and 88 per cent. cut-off. The maximum dynamometer horsepower is 1588.

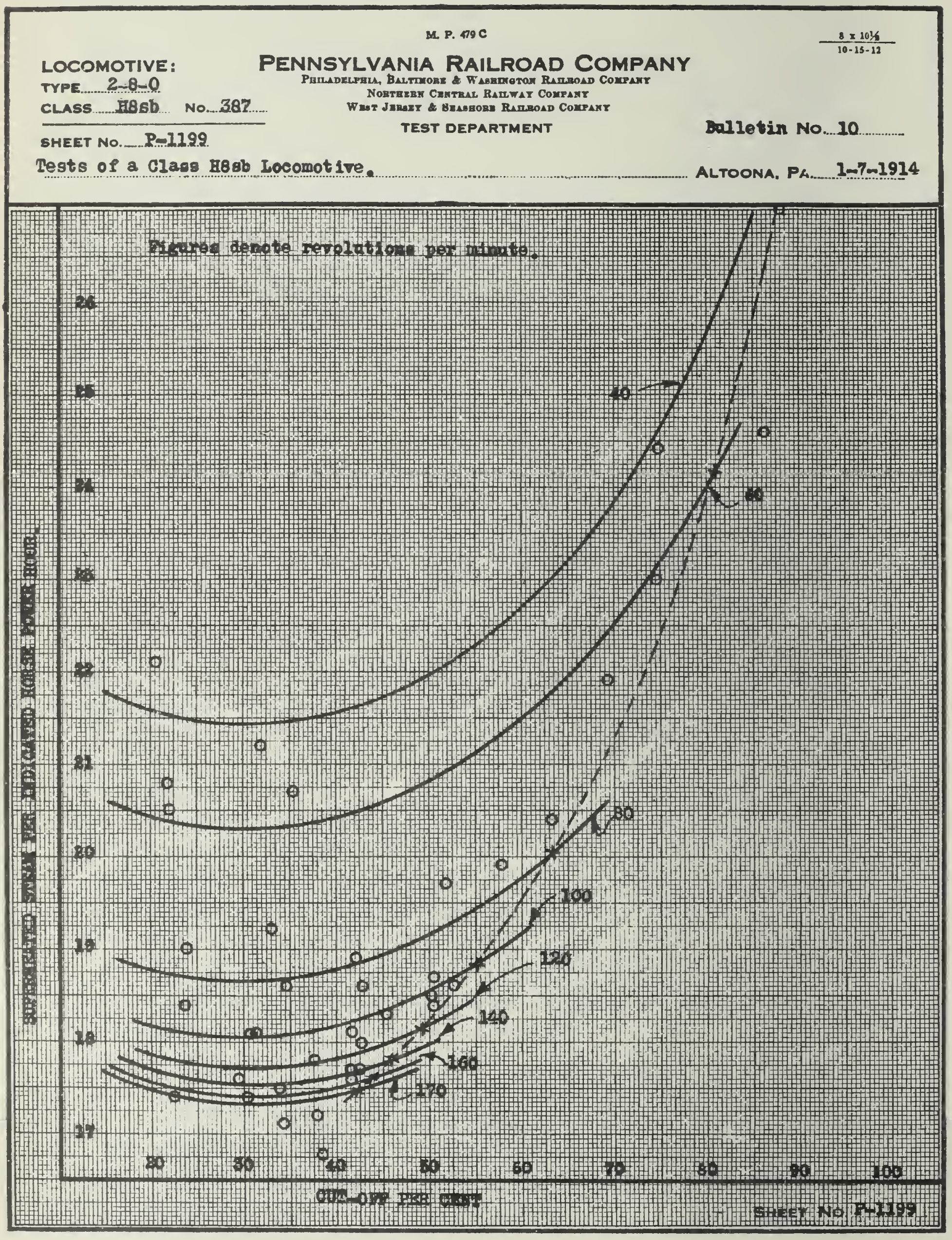

Fig. 48.

STEAM PER INDICATED HORSE-POWER HOUR AND CUT-OFF.

This diagram is used in calculating the maximum drawbar pull. It is observed that the most economical cut-off for this locomotive is at 30 per cent. of the stroke, and the most economical range of cut-off is between 20 and 40 per cent. of the stroke.

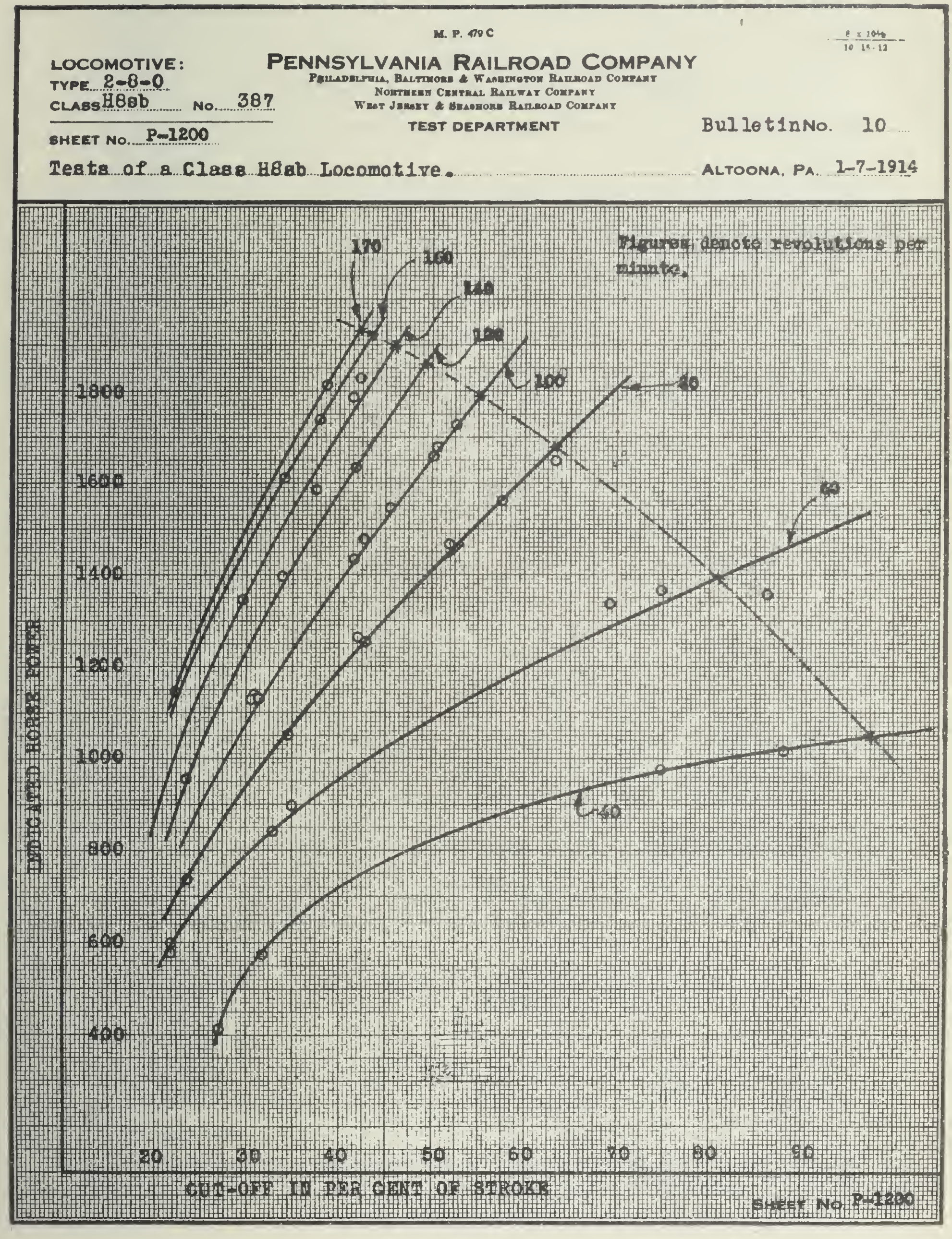

Fig. 49.

INDICATED HORSE-POWER AND CUT-OFF.

This diagram is used in calculating the maximum drawbar pull. The "X" represents the maximum or critical cut-off at each speed. At speeds up to 80 r.p.m. (14 m.p.h.) an increase in cut-off produces but a moderate increase in power. Above this speed the power increases rapidly as the cut-off is extended.

142. The drawbar pull that this locomotive is capable of sustaining at various speeds and cut-offs for a considerable period has been determined by the method as outlined in previous Bulletins (see Bulletin No. 5, page 27). Referring to Figs. 48 and 49, where the steam per horse-power and horse-power are shown for each cut-off, the points X have been selected at like cut-off for each speed, such that the product of these two quantities, is closely equal to the boiler capacity 33,700 pounds of water evaporated per hour.

143. Table XVI following, presents the results in maximum pull obtained by the aid of these diagrams.

TABLE XVI.

CONSOLIDATION TYPE LOCOMOTIVE, CLASS H8SB NO. 387.

Speed		Cut-off in Per Cent.	Steam Per I. H. P. Hour, Pounds	Maximum Indicated Horse-Power	Total Steam Per Hour, Pounds	Average Machine Friction in D.H.P. Pounds	Estimated Maximum D. B. P. Pounds	Actual Maximum D. B. P. Pounds
R. P. M.	M. P. H.							
1	2	3	4	5	6	7	8	9
40	7.19	97.5	32.10	1050	33705	4763	50529	49872
60	10.78	81.0	24.15	1390	33568	4536	44118	44284
80	14.44	63.0	20.05	1680	33684	4735	38894	37502
100	17.97	55.0	18.88	1785	33700	4039	33015	33141
120	21.56	49.0	18.13	1855	33631	3654	28029	27184
140	25.16	46.0	17.80	1895	33731	3752	24009	22791
160	28.75	43.5	17.60	1920	33792	4076	20808	19924
170	30.50	42.0	17.50	1930	33775	4338	19495	17835

144. The calculated maximum drawbar pull thus obtained, is plotted with the speed in m.p.h. in Fig. 50. Eight points are shown representing the maximum drawbar pull for speeds which ranged from 7.2 to 30.5 miles per hour.

145. On the same diagram are shown curves drawn through points of like cut-off representing the actual drawbar pull at various speeds and cut-offs ranging from 20 to 75 per cent.

146. A study of the drawbar pull curve shows that at 18 miles per hour the H8sb locomotive can develop 33,000 pounds drawbar pull, with a wide-open throttle and a 55 per cent. cut-off. At this point for 55 per cent. cut-off the maximum capacity of the boiler is reached. Consequently at speeds greater than 18 miles per hour the cut-off must be below 55 per cent.

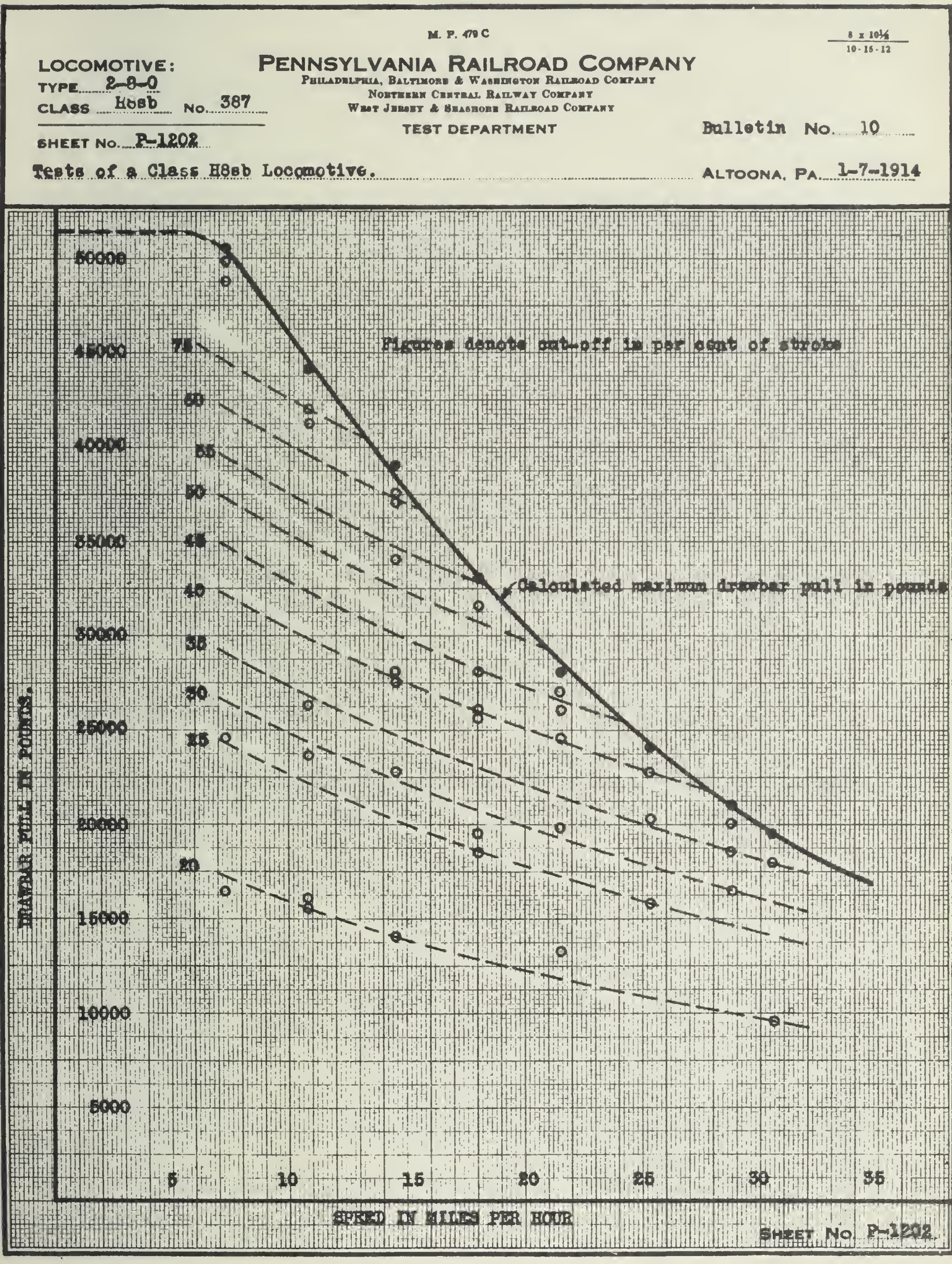

Fig. 50.

DRAWBAR PULL AND SPEED.

The actual and estimated maximum drawbar pulls at speeds from 7 to 30.5 miles per hour.

147. Further, if the drawbar pull is to rise above 33,000 pounds we must increase the cut-off above 55 per cent. and at the same time decrease the speed.

148. There is shown in Fig. 51 the drawbar pull for the H6b and H8b saturated steam locomotives, and the H6sb and H9s superheated steam locomotives. The curves represent the actual performance of these locomotives while in road service and are plotted from dynamometer car records.

149. Referring to Fig. 50, it may be observed that the curve for the H9s locomotive shown in Fig. 51 checks the theoretical curve representing the performance of a similar locomotive, the subject of this Bulletin.

150. Comparing the drawbar pull for the superheated steam locomotive H9s and the saturated steam locomotive H8b, the H9s is 23 per cent. more powerful than the saturated steam locomotive at 12 miles per hour. Likewise comparing the H6sb superheated steam locomotive and the H6b saturated steam locomotive, the H6sb locomotive has a 15 per cent. greater drawbar pull at 12 miles per hour. These curves are representative of the present day possibilities of this class of power, and indicate plainly the advantage to be obtained by a superheater and the still greater gain to be obtained by increasing the diameter of the cylinders when applying a superheater to a saturated steam locomotive, as was done with this H8sb locomotive, making it equivalent to the class H9s.

151. The recommended tonnage rating of the saturated and superheated steam consolidation locomotives in freight service is shown by the following table:

COMPARISON OF TONNAGE RATING ON THREE DIVISIONS SHOWING RECOMMENDED INCREASE IN RATING OF SUPERHEATER OVER SATURATED STEAM LOCOMOTIVES FROM RESULTS OF ROAD TESTS.

New York Division—Eastbound.

Ruling Grade 0.4 per cent. for 1.3 miles, Lawrenceville.
Car Factor 18. Rating Speed 8 m.p.h.

Locomotive Class		Weight of Train, Adjusted Tons	Increase in Rating
H6a-b	Saturated....	4275	
H6sb	Superheater	4950	15.8 per cent. over H6a-b.
H8b	Saturated....	5100	
H8sb	Superheater	5350	5 per cent. over H8b.
H9s	Superheater	5900	15.7 per cent. over H8b. 38 per cent. over H6a-b.

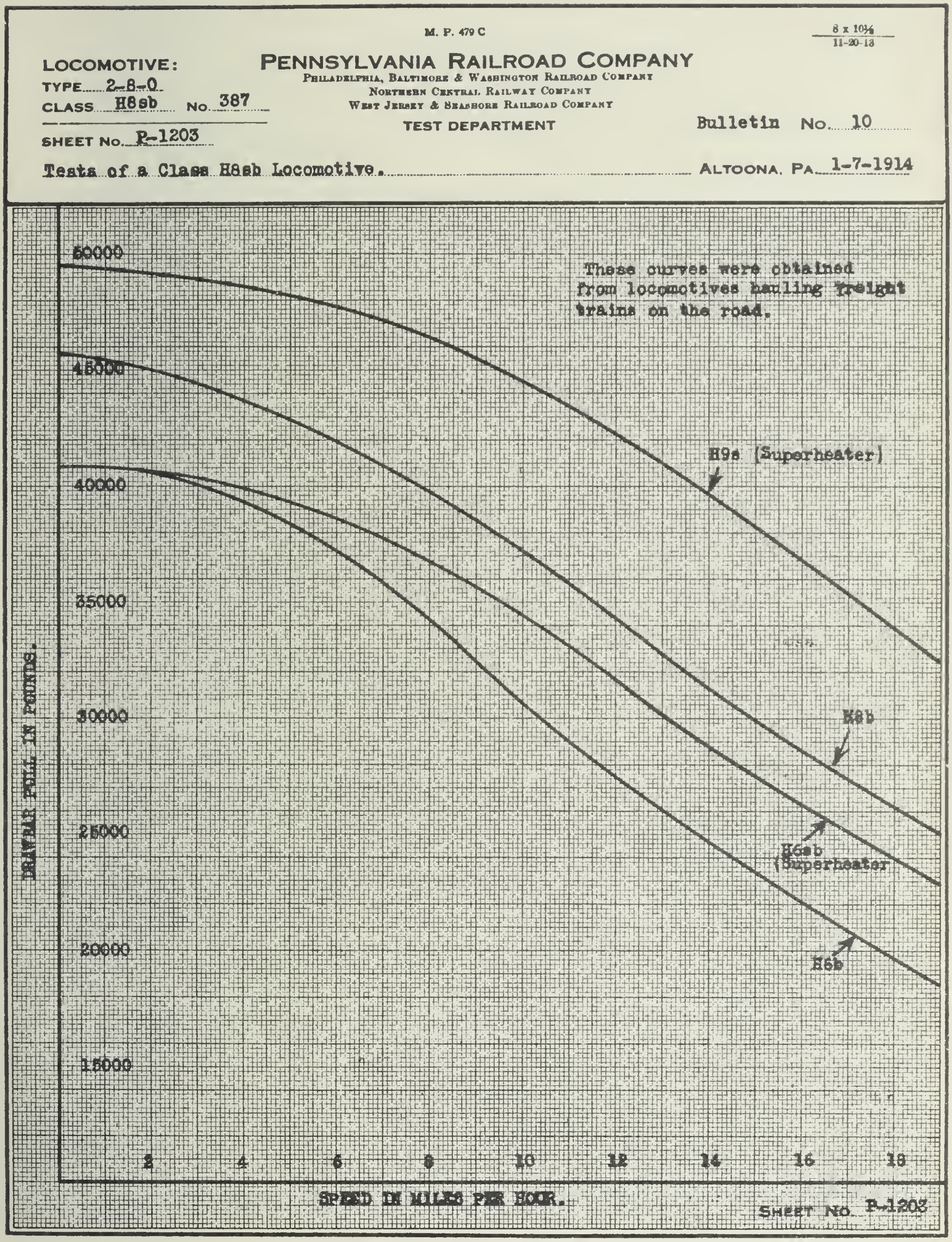

Fig. 51.

DRAWBAR PULL AND SPEED.

Drawbar pulls for the H6b and H8b saturated steam locomotives and the H6sb and H9s superheated steam locomotives from records made by a dynamometer car in road tests. A comparison of pulls at a speed of 12 m.p.h. shows that the superheater, H9s, is 23 per cent. more powerful than the saturated steam H8b, and the H6sb shows a pull 15 per cent. above that of the saturated steam H6b.

Pittsburgh Division.

Car Factor 4.

Rating Speed 10 m.p.h.

	Eastern Slope Ruling Grade 1.88 Per Cent. for 9 Miles		Western Slope Ruling Grade 1.12 Per Cent. for 3.5 Miles	
H6a-b Saturated....	615		1035	
H6sb Superheater.	725	17.9 per cent. over H6a-b.	1225	18.3 per cent. over H6a-b.
H9s Superheater.	850	38.2 per cent. over H6a-b.	1550	50.0 per cent. over H6a-b.

Philadelphia Division.—Low Grade.

Ruling Grade 0.3 per cent. for 25 miles, Creswell.

Car Factor 40.

Rating Speed 10 m.p.h.

H6a-b Saturated....	5100	
H8b Saturated....	5700	
H8sb Superheater	6275	10 per cent. over H8b.
H9s Superheater	6825	19.7 per cent. over H8b. 33.8 per cent. over H6a-b.

These ratings have been worked out from road trials with the dynamometer car and are apparently correct for use on these divisions.

152. To illustrate further the effect of highly superheated steam in the operation of the consolidation type locomotive, Fig. 52 is presented. Here the piston speed, in feet per minute is shown with the weight of steam per i.h.p. hour for the H8sb superheated steam locomotive, the H8b and H6b saturated steam locomotives.

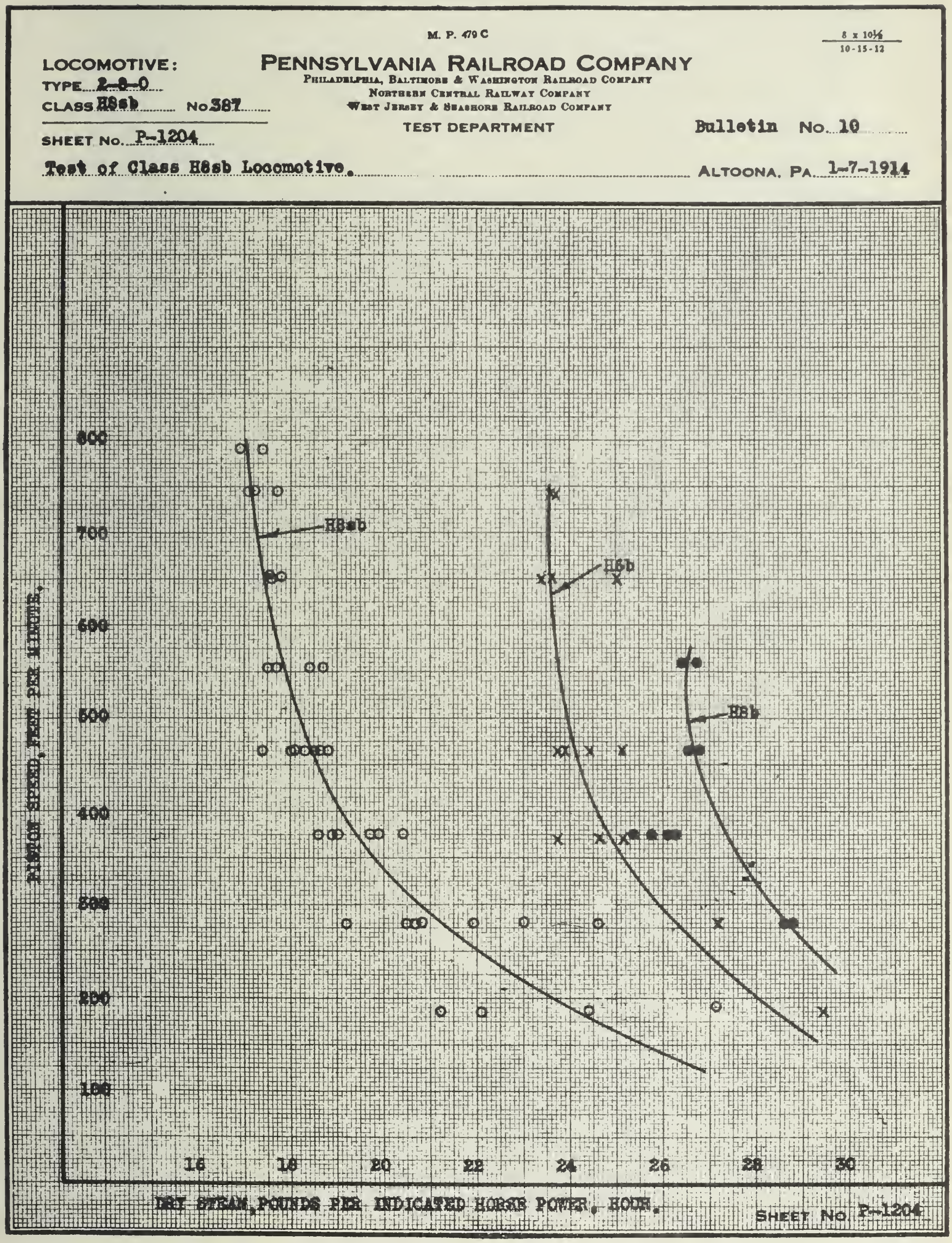

Fig. 52.

PISTON SPEED AND WATER RATE.

This diagram shows a comparison of the effect of piston speed upon water rate with saturated and superheated steam consolidation type locomotives. While the water rate of the H8b appears to be high, there is a remarkable saving in steam by the H8sb superheater when compared with the apparently normal performance of the H6b.

153. The remarkable economy in steam obtained from the H8sb locomotive, throughout the entire range of piston speed cannot fail to attract attention, compared with the two saturated steam locomotives. As previously mentioned in this Bulletin, this H8sb locomotive differs from the H8b saturated steam locomotive, in using superheated steam and being equipped with cylinders one inch larger in diameter. The H6b locomotive, using saturated steam, is a smaller locomotive with smaller driving wheels.

154. The economy of the H6b saturated steam locomotive above that of the larger H8b saturated steam locomotive, is apparent. One reason for this difference in steam consumption is no doubt due to the few tests and the greater amount of condensation in the larger cylinders of the H8b locomotive. The H6b locomotive has cylinders 22 inches in diameter, while those on the H8b locomotive are 24 inches in diameter.

155. It is also possible that had the H8b locomotive been operated at more cut-offs, including the most economical ones at each of the speeds, the curve showing the steam performance on this diagram would have more nearly approached that of the H6b locomotive.

156. The advantage to be derived by the use of highly superheated steam on our consolidation type locomotive in freight service is evident. The economy to be obtained, based on the H8b saturated steam locomotive at 250 feet piston speed is 7.2 pounds of steam per i.h.p. hour or a saving of approximately 24.7 per cent. At higher speeds, approaching 550 feet per minute, the reduction in steam used is 8.6 pounds per i.h.p. hour or a saving of 32.4 per cent.

157. The H8sb superheated steam locomotive and the H6b saturated steam locomotive offer a good comparison also. Comparing the two curves it is observed that the saving in water or steam at a piston speed of 200 feet per minute is 4.3 pounds per i.h.p. hour, or 15.4 per cent. At 750 feet per minute the saving obtained from the superheated steam locomotive is 6.5 pounds of steam per i.h.p. hour or 27.5 per cent.

158. The performance of the H6b saturated steam locomotive is very good. It will be noticed that at the higher speeds a steam consumption per i.h.p. hour as low as 23.5 pounds was obtained.

M. P. 479—A

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LOCOMOTIVE:
TYPE 2-8-0
CLASS H8sb No. 387

PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

TEST DEPARTMENT

Bulletin No. 10

SHEET NO. P-1205

Tests of a Class H8sb Locomotive. ALTOONA, PA. 1-7-1914

MACHINE FRICTION.

Test No.	Test Designation	Duration of Test Minutes	Machine Friction in Horse Power	Mean Effective Press. Lbs. Per Square Inch	Drawbar Pull Pounds	Steam to Engines Per Hour, Pounds	Dry Coal Fired Per Hour, lb	Machine Efficiency Per cent
			395	396	397			398
3207	40-20-F	120	97.8	17.89	5081	2836.2	304.2	76.27
3210	40-30-F	120	105.3	19.26	5495	2727.3	327.5	81.76
3246	40-75-F	30	99.1	18.13	5171	2694.5	396.4	89.87
3247	40-88-F	15	63.3	11.58	3303	1829.4	396.3	93.79
3205	60-20-F	45	130.9	15.96	4534	3487.2	409.7	78.15
3206	60-20-F	105	127.6	15.56	4419	3349.5	384.1	77.98
3209	60-30-F	90	164.6	20.07	5726	3919.1	493.8	80.46
3227	60-35-F	90	139.4	17.00	4849	3418.1	430.8	84.50
3242	60-68-F	30	134.1	16.35	4665	3257.3	649.0	89.96
3245	60-75-F	30	132.1	16.11	4596	3368.6	832.2	90.32
3244	60-86-F	15	85.1	10.38	2960	2245.8	454.4	93.73
3201	80-20-F	120	192.6	17.61	5003	4959.5	631.0	73.74
3202	80-30-F	90	176.4	16.13	4582	3935.5	502.7	83.20
3203	80-40-F	30	201.9	18.46	5245	4544.8	557.2	84.01
3204	80-40-F	105	172.5	15.78	4481	3715.7	508.9	86.23
3238	80-55-F	30	171.7	15.70	4480	3835.8	772.7	88.31
3239	80-58-F	60	146.5	13.40	3822	3217.2	622.6	90.61
3241	80-63-F	60	212.0	19.39	5531	4960.8	759.0	87.15
3208	100-25-F	60	233.5	17.08	4852	5328.5	635.1	79.37
3211	100-25-F	30	242.0	17.71	5051	5553.9	791.3	78.74
3212	100-25-F	120	188.6	13.80	3937	3947.4	489.4	83.29
3213	100-40-F	30	237.5	17.38	4957	5087.3	774.3	83.94
3214	100-40-F	120	183.6	13.43	3832	3807.9	605.9	87.19
3215	100-45-F	120	182.2	13.33	3803	3777.0	641.3	88.23
3236	100-50-F	60	140.4	10.27	2931	2837.5	453.5	91.53
3237	100-55-F	60	141.8	10.37	2949	2874.3	521.8	91.80
3223	120-20-F	120	186.7	11.38	3247	4264.2	519.0	80.50
3221	120-30-F	120	252.1	15.37	4385	5384.9	756.3	81.91
3230	120-40-F	120	209.1	12.75	3621	4255.2	694.2	87.19
3216	120-50-F	60	190.1	11.59	3307	4005.4	737.6	88.67
3217	120-50-F	45	213.4	13.01	3712	4449.4	851.5	88.03
3225	140-25-F	90	271.5	14.19	4048	5973.0	822.7	79.76
3218	140-35-F	120	232.6	12.16	3468	4845.1	874.6	85.36
3220	140-40-F	60	250.9	13.11	3741	5130.9	865.6	85.95
3229	160-30-F	120	330.2	15.10	4289	7089.4	1066.6	79.50
3222	160-35-F	60	312.6	14.29	4078	6564.6	1119.1	82.01
3235	160-40-F	60	295.9	13.53	3860	6234.6	1077.1	83.83
3228	170-20-F	120	352.2	15.16	4324	8819.1	1292.6	69.31
3224	170-35-F	60	354.4	15.25	4351	7414.0	1183.7	80.46

SHEET NO. P-1205

Table XVII.

MACHINE FRICTION.

This table is presented to show the friction of the locomotive machinery as measured in terms of horsepower, mean effective pressure, drawbar pull, water rate and coal consumption.

159. With the H8sb superheated steam locomotive, the steam consumption per indicated horse-power hour is below that for the E3sd, K2sa, E6s and K29s passenger locomotives (reported upon in Bulletins 11, 18, 19 and 21) using superheated steam, when the piston speed is 800 feet per minute or less. In the case of the Hannover compound locomotive, using a low degree of superheat, we find that it is more economical in steam than the H8sb locomotive at piston speeds below 600 feet per minute. (Bulletin 11, Fig. 47.)

160. It should also be observed that at a piston speed of 800 feet per minute the steam consumption of this superheated steam locomotive is as low as 17 pounds per indicated horse-power hour or a little better than that obtained from the K2sa locomotive at a piston speed of 1300 feet per minute.

Machine Friction.

161. Table XVII is arranged and presented to show the machine friction obtained from this locomotive in terms of equivalent horse-power, mean effective pressure in pounds per square inch, drawbar pull in pounds, steam to engines in pounds per hour, dry coal fired per hour in pounds and the machine efficiency in per cent. The table is arranged according to speed from 40 to 170 r.p.m.; each speed is arranged according to the increase in cut-off.

162. An analysis of the table indicates that the time element or the duration of the test is a factor to be taken into consideration, when determining the machine efficiency of the locomotive, hence the inconsistency of a part of this data. As an example we may refer to Tests Nos. 3208, 3211, 3212 which were run at a speed of 100 r.p.m. and a cut-off of 25 per cent. with a wide-open throttle. The duration of these tests was 60, 30 and 120 minutes respectively. The machine friction in horse-power is seen to decrease from 242 horse-power to 233.5 horse-power and then to 188.6 horse-power, and there is observed a similar decrease in the other equivalents referred to in this table. The machine efficiency, however, is observed to increase at the same speed and cut-off as the duration of the tests is increased as should be expected.

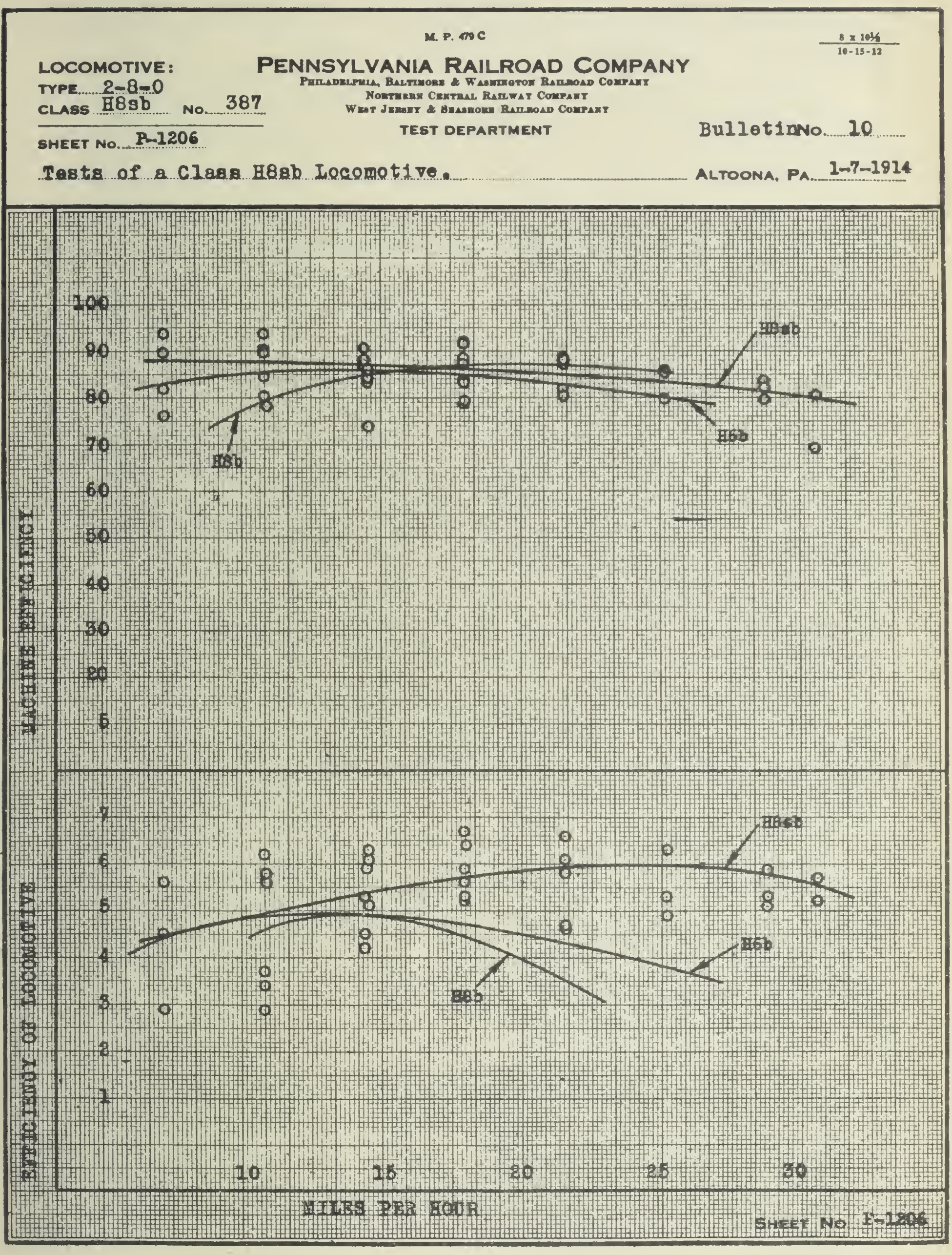


Fig. 53.

MACHINE EFFICIENCY AND THERMAL EFFICIENCY AT DIFFERENT SPEEDS.

The machine efficiency of the H8sb locomotive is a fair average for the three consolidation type locomotives. The greater thermal efficiency of the H8sb superheated steam locomotive at speeds above 15 miles per hour is apparent.

163. Comparing Tests Nos. 3213 and 3214, run at the same speed and cut-off, we cannot fail to note this difference in machine friction due to the difference in the test duration.

164. The machine friction, in terms of drawbar pull, ranged from 2931 pounds to 5726 pounds. The average machine friction in terms of drawbar pull for all of the tests was 4235 pounds.

165. The machine efficiency in per cent. ranges from 69.31 to 93.79 per cent.

Efficiency of the Locomotive.

166. The machine efficiency of the H8sb locomotive, shown graphically in the upper portion of Fig. 53, falls off slightly as the speed increases. Between the speeds of 10 and 30 miles per hour the machine efficiency is 80 per cent. or above. It is noticeable that above the speed of 19 miles per hour the H8b locomotive has a slightly higher machine efficiency than the H8sb locomotive, which may possibly be due to the larger cylinders of the latter. The machine efficiency of the H6b locomotive is slightly below that of the H8sb locomotive.

167. In the lower half of this diagram (Fig. 53) is similarly presented the thermal efficiencies of the H8sb, H8b and H6b locomotives.

168. The thermal efficiency of the H8sb superheated steam locomotive is seen to increase with the speed up to 25 miles per hour, after that it drops off. The thermal efficiency at this speed is 6 per cent.

169. A comparison of the curves indicating the thermal efficiencies for the H8b and H6b saturated steam locomotives shows a rapid drop in the thermal efficiencies of both locomotives after a speed of 19 miles per hour has been attained. Especially is this noticeable with the H8b locomotive due to its greater steam consumption per i.h.p. hour (see Fig. 47).

Coal and Water Saving.

170. The coal and water saving which is obtained by the use of a superheater and larger cylinders on this locomotive, is shown on Figs. 54 and 55. A direct comparison between the H8sb and H8b locomotives is possible in this instance. As previously

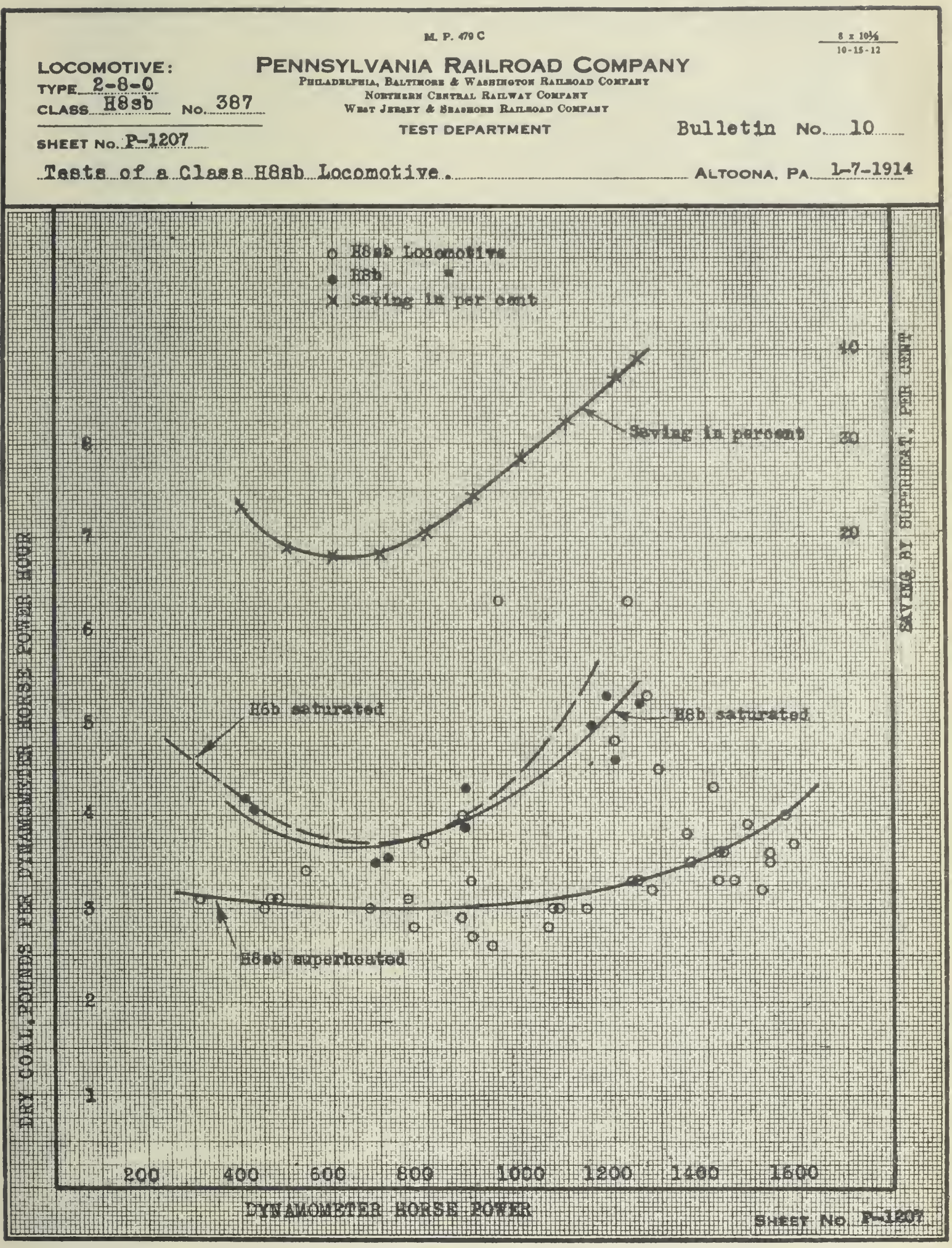


Fig. 54.

COAL PER DYNAMOMETER HORSE-POWER.

This diagram shows that at full load, the application of a superheater and large cylinders to an H8b saturated steam locomotive effects a saving of 39 per cent. in coal.

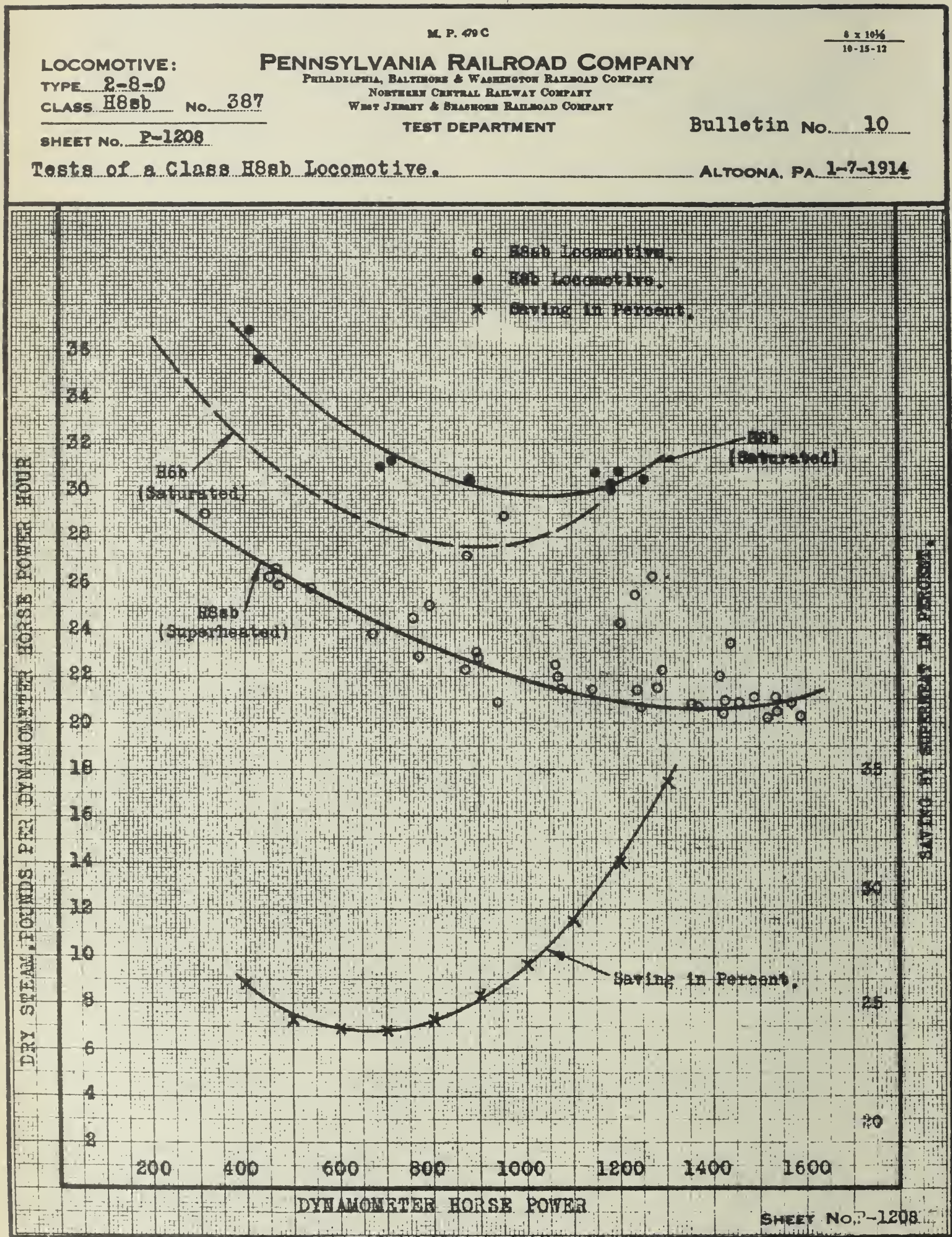


Fig. 55.

STEAM PER DYNAMOMETER HORSE-POWER.

Above is shown the saving in steam obtained by adding a superheater and larger cylinders to a class H8b saturated steam locomotive. The saving thus effected at 1250 dynamometer horse-power reaches 32.8 per cent.

mentioned in this Bulletin the only difference existing between the two locomotives, is that the H8sb locomotive is equipped with a fire-tube superheater and larger cylinders, designed for superheated steam. This locomotive was originally designed as an H8b saturated steam locomotive with cylinders 24 x 28 inches. It should be kept in mind that the H8sb locomotive herein described (No. 387) was rebuilt with larger cylinders as an experiment, and further, that it is practically similar to the H9s locomotive now in service.

171. Referring to Fig. 54, there is plotted the dry coal in pounds per dynamometer horse-power hour with the dynamometer horse-power. Three curves are presented showing the performance of the H8sb, H8b and H6b locomotives. The performance of the H6b saturated locomotive is not quite so good as that for the H8b saturated locomotive, with an exception at 800 dynamometer horse-power, where the coal consumption of both locomotives is the same.

172. Comparing the curves for the H8sb superheated steam locomotive and the H8b saturated steam locomotive, it is seen that the economy in fuel consumption increases with the dynamometer horse-power developed. The saving in coal effected by the use of superheated steam in the H8sb locomotive is 23 per cent. at 400 d.h.p., drops to 18 per cent. at 600 d.h.p., and from that point increases to 39 per cent. at 1250 d.h.p., the maximum dynamometer horse-power developed with the H8b saturated locomotive. Thus, it is seen that at full load the application of a superheater and larger cylinders effects a saving of 39 per cent. in coal.

173. The economy in water or steam per d.h.p. hour, as compared with the dynamometer horse-power output of the locomotive is shown on Fig. 55. Here, likewise, we present curves showing the steam consumption per d.h.p. hour for the H8sb, H8b and H6b locomotives.

174. Comparing the curves representing the water rates for the H8b and H6b saturated steam locomotives, the better water rate of the H6b locomotive is observed. This is especially true at the lower dynamometer horse-powers. As the dynamometer horse-power output approaches 1200 the steam consumption of

the H6b, saturated steam locomotive, is seen to approach and will coincide with the consumption of the H8b locomotive if the H6b locomotive is forced to 1300 d.h.p.

175. Observing the curves for the H8sb superheated steam locomotive and the H8b saturated steam locomotive, the economy in the water rate obtained from the superheated steam locomotive is at once apparent. At 400 d.h.p. the saving is 25.2 per cent.; this saving drops to 23.8 per cent. at 650 d.h.p., whereupon it rapidly increases with an increase in the dynamometer horse-power to 32.8 per cent. at 1250 d.h.p.

176. The conclusions confirmed by these tests on an experimental H8sb locomotive, are that the saving in water and coal increases with the increased power developed by the locomotive. At the power limit of the saturated steam locomotive we may anticipate a saving in coal of 39 per cent. and a saving in water 32.8 per cent., and this is an important economy, as it may be further utilized for increasing the capacity of the locomotive. In other words, it is possible to give this locomotive a larger tonnage rating than its predecessor, the H8b saturated steam locomotive. This increase in rating may approximate 32 per cent. in view of the fuel and water economy above mentioned.

177. It was observed in Fig. 51, that the increase in drawbar pull for the H9s superheater locomotive above that of the H8b, increased from 10 per cent. at starting to 25 per cent. at 30 miles per hour.

178. In view of this fact it would appear that the full possibilities of the H9s locomotive were not realized, especially at low speeds and it is probable that, as the locomotive crews become more familiar with the operation of this class of locomotive, its possibilities as set forth in this text will be utilized to a greater extent.

179. Higher speeds may also be maintained with the H8sb superheated steam locomotive than with the H8b saturated steam locomotive when hauling trains of like tonnage. This is shown on Fig. 51, illustrating the greater drawbar pulls of the superheated steam locomotive at the higher speeds.

180. The increase in the dynamometer horse-power gained through the reduction in steam per d.h.p. hour, assuming 1400 d.h.p. as the maximum power output of the H8b locomotive is 14 per cent.

CONCLUSIONS.

BOILER.

1. When the combustion rate exceeds 5500 pounds of coal per hour, or 100 pounds per square foot of grate, the indications are, that the coal is very imperfectly burned. (Par. 36.) It was found that the carbon monoxide in the smokebox gases rapidly increased at rates of firing above 5000 pounds per hour. This is an indication of insufficient air supply at the high rates of combustion. (Par. 45.)

2. There is an equal vacuum or draft both front and back of diaphragm, and this would indicate that there is little or no loss on account of the presence of the diaphragm. (Par. 39.)

3. The heat absorbed by the superheater is found to be less than 10 per cent. of that absorbed by the water heating surface. (Par. 48.)

4. A satisfactory self-cleaning arrangement of smokebox for this locomotive is shown in Fig. 10. With this arrangement the smallest opening for gases is 3.88 square feet or 54 per cent. of the opening through the tubes. (Par. 53.)

5. It is believed that an improvement would be made by decreasing the width of the centre grate bearer so that the active shaking part of the grate would be increased. Such an improved form of grate is now used on the E6s and H9s locomotives. (Par. 105.)

6. The loss in steam pressure between the boiler and cylinders under the condition of maximum evaporation is 11 pounds. (Par. 113.)

ENGINES.

7. The maximum indicated horse-power obtained was 1830. (Par. 115.)

8. The dry coal per indicated horse-power ranged between 2.2 and 3.9 pounds. (Par. 115.)

9. The steam per indicated horse-power ranged between 16.8 and 22.1 pounds per hour. (Par. 115.)

10. There is a remarkable uniformity in the coal consumption per indicated horse-power hour. It is approximately 2.5 pounds up to 1300 indicated horse-power, and from there on it increases to 3.5 pounds at 1800 indicated horse-power. (Par. 123.)

11. Comparing the H8b and H8sb locomotives there is a saving in steam of 26.3 per cent. at 500 indicated horse-power and 35 per cent. at 1500 indicated horse-power. (Par. 128.)

12. The increase in cylinder diameter appears to be partly responsible for the saving in steam, as it makes possible the use of short cut-offs. (Par. 130.)

Locomotive.

13. The operation of this locomotive is most economical at a cut-off of 30 per cent., while an economical range of cut-off lies between 20 and 40 per cent. (Par. 139.)

14. This consolidation type locomotive develops a maximum drawbar pull of 49,872 pounds, and this is about 3600 pounds above its rated pull. (Par. 134.)

15. Comparing the H8b with the H9s we find, from road tests, that the H9s is 23 per cent. more powerful than the saturated steam locomotive at a speed of 12 miles per hour. (Par. 150.)

16. Comparing the H8b and H8sb, the saving in coal by the superheater locomotive with larger cylinders is between 23 per cent. and 39 per cent. The economy in steam is between 23.8 per cent. and 32.8 per cent. (Pars. 172 and 175.)

Recommendations.

1. The class H9s, as now being built, excepting the front end arrangement, embodies the changes desirable for the improvement of the class H8sb, as indicated by these test results, and with this in mind, we would recommend the following:

(*a*) When new cylinders are required, 25 × 28 inch cylinders of the H9s class should be applied to the class H8sb.

(*b*) When new grates are applied to the H8sb class, the H9s class grate should be used. (Par. 105.)

2. In order to reduce the somewhat excessive vacuum in the ashpan, additional openings in it should be provided, if possible, so that the total area of the openings will be at least 8.5 square feet. (Par. 40.)

3. We would recommend the application of the front end arrangement, as shown in Fig. 10, to all H8sb and H9s locomotives. (Par. 54.)

C. D. YOUNG,
Engineer of Tests.

APPROVED:
J. T. WALLIS,
General Supt. Motive Power.

TEST DEPARTMENT,
ALTOONA, PENNA.,
February 2, 1914.

(M. P Special.) (Sheet No 1.)

PENNSYLVANIA RAILROAD COMPANY.

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY.
NORTHERN CENTRAL RAILWAY COMPANY.
WEST JERSEY & SEASHORE RAILROAD COMPANY.

TEST DEPARTMENT.
LOCOMOTIVE TESTING PLANT.

TEST OF LOCOMOTIVE No. 387 TYPE 2-8-0 CLASS H8sb BUILT AT Juniata Shops, Altoona, Penna., 1909

Consolidation type locomotive with arch and superheater 25 in. diam. cylinders PRESENTED FOR TEST BY Pennsylvania Railroad Company

TESTED AT Altoona Locomotive Test Plant TESTED April 1913 TEST Nos. 3201 TO 3247 SERIES No. 3200

No.	DESCRIPTION. DIMENSIONS AND PROPORTIONS.	
	DRIVING WHEELS.	
1	Number of pairs	4
2	Approximate diameter, inches	62
	MEASURED CIRCUMFERENCE, FEET.	
3	Right, No. 1	15.81
4	" " 2	15.81
5	" " 3	15.81
6	" " 4	15.81
7	" " 5	-
8	Left, " 1	15.81
9	" " 2	15.81
10	" " 3	15.81
11	" " 4	15.81
12	" " 5	-
13	Average	15.81
	ENGINE TRUCK WHEELS.	
14	Number	2
15	Diameter, inches	32.25
	TRAILING WHEELS.	
16	Diameter, inches	0
	WHEEL BASE, FEET.	
17	Driving wheel base	17.03
18	Total wheel base	25.85
19	Gauge of wheels, in inches	56.5
	DESCRIPTIONS, DIMENSIONS AND PROPORTIONS.	
	VALVES.	
82	Type	Piston
83	Design	
84	Per cent. of balanced to total area	100
85	Type of link motion	Walschaerts
	GREATEST VALVE TRAVEL, INCHES.	
86	High pressure, right	5.84
87	" " left	5.72
88	Low " right	-
89	" " left	-
	STEAM LAP OF VALVE, INCHES.	
90	High Pressure, right, head end	0.88
91	" " " crank "	0.88
92	" " left, head "	0.90
93	" " " crank "	0.90
94	Low " right, head "	-
95	" " " crank "	-
96	" " left, head "	-
97	" " " crank "	-
	EXHAUST LAP OF VALVE, INCHES.	
98	High Pressure, right, head end	0.13
99	" " " crank "	0.13
100	" " left, head "	0.13
101	" " " crank "	0.13
102	Low " right, head "	-
103	" " " crank "	-
104	" " left, head "	-
105	" " " crank "	-
	MISCELLANEOUS.	
106	Cylinder lagging material	Magnesia
107	" jacket "	Sheet iron
108		
109		

No.	WEIGHT OF ENGINE WITH WATER AT 2ND GAUGE COCK AND NORMAL FIRE, IN POUNDS.	
20	On truck	29600
21	" 1st drivers	59300
22	" 2nd "	52100
23	" 3rd "	57400
24	" 4th "	51100
25	" 5th "	-
26	" trailers	-
27	Total	249500
28	" on drivers	219900
	CYLINDERS.	
29	High pressure, number	2
30	Low "	-
31	Arrangement	Outside
	DIAMETER, INCHES.	
32	High pressure, right	25.016
33	" left	24.996
34	Low " right	-
35	" " left	-
	STROKE OF PISTON, FEET	
36	High pressure, right	2.329
37	" " left	2.320
38	Low " right	-
39	" " left	-
110		
111		
112		
	BOILER.	
113	Type	Belpaire, Wide Firebox
114	Outside diameter, 1st ring, inches	7.85
	TUBES.	
115	Number	Small 265 Large 36
116	Outside diameter, inches	Small 2 Large 5-7/16
117	Thickness, inches	Small 0.125 Large 0.148
118	Length between tube sheets, inches	180.19
119	Total fire area, square feet	7.31
120	Serve Tubes, number of ribs	-
121	" sq. in. of inside surface in one in. of length	-
122		
123		
124	Boiler Pressure, lbs. per sq. in.	205
	SUPERHEATER.	
125	Number of tubes	144
126	Outside diameter, inches	1.50
127	Thickness, inches	0.148
128	Length of tubes, inches Total	23255
129	Heating surface fireside tube sq. ft.	766.2
130	" " " header	18.20
131	" " Return bends	24.21
	FIRE BOX (SIZE INSIDE, INCHES.)	
132	Length. At level of door inches.	113.00
133	Width	68.0
134	Depth, front end	69.5
135	" back "	58.0
136	Volume, cubic feet	199.15
137	Air inlets to ashpan, sq. ft.	7.52
138	Volume of arch pipe cu. ft.	1.38
139		
140		

No.	CLEARANCE PER CENT. OF PISTON DISPLACEMENT.	
40	H. P., right, head end	
41	" " crank "	
42	" left, head "	
43	" " crank "	
44	L. P., right, head "	-
45	" " crank "	-
46	" left, head "	-
47	" " crank "	-
	RECEIVER, CUBIC FEET.	
48	Volume, right side	-
49	" left "	-
	STEAM PORTS, INCHES. (For piston valves the length equals the circumference of inside of bushing minus the sum of the widths of ridges.)	
50	H. P. admission, right, head end, length	31.84
51	" " " " " width	2.01
52	" " " crank " length	32.03
53	" " " " " width	2.00
54	" " left, head " length	32.38
55	" " " " " width	2.00
56	" " " crank " length	31.81
57	" " " " " width	2.00
58	L. P. " right, head " length	-
59	" " " " " width	-
	FIRE DOORS.	
141	Number	One
142	Area, square feet	1.59
143		
	GRATES.	
144	Style	Rocking Finger
145	Total area, square feet	55.34
146	" " dead grates, square feet	
147	Width of air spaces, inches	
	AIR INLET AREAS, SQUARE FEET.	
148	Through firebox sides	0.017
149	" grates	14.67
150	" fire doors	0.07
151	Total air inlets, (148), (149) and (150)	14.76
152	Ratio " " (148) to grate area (145)	0.27
153	" " " (151) to " " (145)	0.27
	HEATING SURFACE, SQUARE FEET.	
154	Of the tubes, water side Large 756.70 Small	2083.51
155	" " " fire " " 714.60 "	1823.07
156	" " firebox, fire side Including arch pipe	189.90
157	" " superheater, fire side	808.98
158	Total, based on inside of firebox and inside of tubes including superheater sq. ft.	3536.55
159	" " " " " outside of tubes including " superheater	3839.09
	BOILER VOLUMES With water surface at level of second gauge cock.	
160	Water space, cubic feet	406.04
161	Steam " "	108.86
	EXHAUST NOZZLE.	
162	Double or single	Single
163	Size of right, inches	
164	" " left, " Rectangular	4¾ x 6½ ins.
165	Area of right, square inches	
166	" " left, " "	
167	Total area, square inches	30.88

No.		
60	L. P. admission, right, crank end, length	-
61	" " " " " width	-
62	" " left, head " length	-
63	" " " " " width	-
64	" " " crank " length	-
65	" " " " " width	-
66	H. P. exhaust, right, length	
67	" " " width	
68	" " left, length	
69	" " " width	
70	L. P. " right, length	-
71	" " " width	-
72	" " left, length	-
73	" " " width	-
	PISTON RODS, DIAMETER, INCHES.	
74	High pressure, right	3.991
75	" " left	3.846
76	Low " right	-
77	" " left	-
	TAIL RODS, DIAMETER, INCHES.	
78	High pressure, right	-
79	" " left	-
80	Low " right	-
81	" " left	-
	REVERSE LEVER.	
168	H. P. cylinder, notches forward of centre	19
169	L. P. " " " " "	
170		
	RATIOS.	
171	Heating surface (158) to grate area (145)	63.90
172	Fire area through tubes (119) to grate area (145)	0.132
173	Firebox heating surface (156) to grate area (145)	3.43
174	Tube surface (154) to firebox heating surface (156)	13.35
175	Firebox volume (136) to grate area (145)	3.59
176		
177		
178		
	CONSTANTS	
179	For dynamometer H. P., (power developed when the speed is one R. P. M. and the pull is one pound)	0.0004773
	FOR INDICATED HORSE POWER, (power developed at one R. P. M. and one pound M. E. P.)	
180	High Pressure Cylinder, right, head end	0.03469
181	" " " " crank "	0.03381
182	" " " left, head "	0.03460
183	" " " " crank "	0.03368
184	Low " " right, head "	-
185	" " " " crank "	-
186	" " " left, head "	-
187	" " " " crank "	-
	PISTON DISPLACEMENT, CUBIC FEET.	
188	High pressure Cylinder, right, head end	7.950
189	" " " " crank "	7.748
190	" " " left, head "	7.906
191	" " " " crank "	7.718
192	Low " " right, head "	-
193	" " " " crank "	-
194	" " " left, head "	-
195	" " " " crank "	-

(M. P. Special.) TEST OF LOCOMOTIVE No. 387 TYPE 2-8-0 CLASS H8eb (Sheet No. 3)

SUMMARY OF AVERAGE RESULTS.

Test Number	Laboratory Designation	Duration of Test, Hours	Speed: Revolutions: Total	Speed: Revolutions: Average Per Minute	Speed: Equivalent: Speed in Miles Per Hour	Speed: Equivalent: Piston Speed in Feet Per Minute	Position of Levers: Reverse, Notches From Front End	Position of Levers	Position of Levers: Throttle	Position of Levers		Temperature, Degrees Fahrenheit, of: Smoke Box: By Thermometer	Smoke Box: By Pyrometer	Laboratory: Dry Bulb	Laboratory: Wet Bulb	Steam in Branch Pipe	Feed Water	Fire Box by Pyrometer		Steam per Hour to Engines, Pounds	Fuel Loss Due to Steam Loss Pounds per Hour	Steam Lost from Boiler Pounds per Hour
		196	197	198	199	200	201	202	203	204	205	206	207	208	209	210	211	212	213	214	215	216
3207	40-20-F	2.00	4800	40	7.22	186.0	19.0		Full				488	64	60	485.5	50.4	1924		9116	19.67	189
3210	40-30-F	2.00	4800	40	7.19	186.0	17.5		"				528	52	46	519.2	49.3	2130		12227	81.63	720
3246	40-75-F	0.50	1200	40	7.19	186.0	10.0		"				658	58	52	558.5	48.0	2360		23892	30.60	2280
3247	40-88-F	0.25	600	40	7.19	186.0	2.5		"				660	57	51	559.3	48.0	2380		27624	40.61	2010
3205	60-20-F	0.75	2700	60	10.83	279.0	19.0		"				500	55	52	489.3	43.5	1780		12474	25.66	222
3206	60-20-F	1.75	6300	60	10.83	279.0	19.0		"				480	50	47	497.3	45.7	1879		11865	21.33	189
3209	60-30-F	1.50	5400	60	10.78	279.0	17.5		"				522	56	51	518.4	51.6	2158		16137	36.33	295
3227	60-35-F	1.50	5400	60	10.78	279.0	17.0		"				548	59	53	523.0	55.9	2243		18633	37.42	302
3242	60-68-F	0.50	1800	60	10.78	279.0	12.0		"				655	63	56	560.0	47.3	2410		29195	29.73	1570
3245	60-75-F	0.50	1800	60	10.78	279.0	10.0		"				670	54	51	551.3	48.3	-		31422	70.17	287
3244	60-86-F	0.25	900	60	10.78	279.0	5.0		"				673	66	57	564.0	48.0	2370		33468	36.36	180
3201	80-20-F	2.00	9600	80	14.44	372.0	19.0		"				564	54	50	514.2	44.0	2187		13927	81.33	649
3202	80-30-F	1.50	7200	80	14.44	372.0	17.5		"				599	59	54	521.2	44.7	2160		19489	27.40	217
3203	80-40-F	0.50	2400	80	14.44	372.0	16.5		"				645	61	56	533.0	43.0	2265		23888	30.50	251
3204	80-40-F	1.75	8400	80	14.44	372.0	16.5		"				626	58	57	539.5	44.0	2376		23259	28.53	210
3238	80-55-F	0.50	2400	80	14.38	372.0	15.0		"				645	59	55	567.0	50.7	2360		28983	62.22	827
3239	80-58-F	1.00	4800	80	14.38	372.0	14.0		"				637	55	51	580.9	48.0	2395		31062	60.69	422
3241	80-63-F	1.00	4800	80	14.38	372.0	13.0		"				669	66	57	596.3	48.2	-		33642	28.57	188
3208	100-25-F	1.00	6000	100	18.05	465.0	18.0		"				610	62	57	545.0	46.5	2335		20497	22.46	190
3211	100-25-F	0.50	3000	100	17.97	465.0	18.0		"				573	64	51	545.5	53.0	2360		20577	43.40	309
3212	100-25-F	2.00	12000	100	17.97	465.0	18.0		"				568	61	57	542.2	46.4	2302		19681	55.74	202
3213	100-40-F	0.50	3000	100	17.97	465.0	16.5		"				624	67	59	542.0	47.0	2390		26584	39.06	259
3214	100-40-F	2.00	12000	100	17.97	465.0	16.5		"				627	56	53	562.1	47.8	2310		25906	47.17	300
3215	100-45-F	2.00	12000	100	17.97	465.0	16.0		"				637	60	53	565.8	49.7	2408		28303	31.70	188
3236	100-50-F	1.00	6000	100	17.97	465.0	15.5		"				646	74	64	566.9	50.0	2463		30650	30.00	189
3237	100-55-F	1.00	6000	100	17.97	465.0	15.0		Full				651	58	52	570.9	48.7	2510		32192	42.34	235
3223	120-20-F	2.00	14400	120	21.56	558.0	19.0		"				539	56	53	514.8	50.4	2148		17608	32.29	269
3221	120-30-F	2.00	14400	120	21.56	558.0	17.5		"				595	65	62	543.1	50.1	2344		24397	38.75	279
3230	120-40-F	2.00	14400	120	21.56	558.0	16.5		"				618	58	50	574.2	50.5	2403		28957	30.52	188
3216	120-50-F	1.00	7200	120	21.56	558.0	15.5		"				640	70	65	570.3	47.8	2423		31336	31.50	172
3217	120-50-F	0.75	5400	120	21.56	558.0	15.5		"				646	67	62	578.8	49.2	2405		32721	34.67	182
3226	140-25-F	1.50	12600	140	25.16	651.0	18.0		"				611	60	54	563.8	48.0	2304		23543	30.60	224
3218	140-35-F	2.00	16800	140	25.16	651.0	17.0		"				634	69	64	546.5	47.8	2308		28250	32.80	183
3220	140-40-F	1.00	8400	140	25.16	651.0	16.5		"				634	65	60	554.9	50.0	2425		31399	31.54	188
3229	160-30-F	2.00	19200	160	28.75	744.0	17.5		"				537	54	49	568.8	48.8	2315		27487	39.88	268
3222	160-35-F	1.00	9600	160	28.75	744.0	17.0		"				650	63	56	552.9	51.8	2377		29934	31.69	187
3235	160-40-F	1.00	9600	160	28.75	744.0	16.5		"				651	70	61	577.1	52.2	2387		32320	38.77	226
3228	170-20-F	2.00	2400	170	30.50	790.0	19.0		"				563	58	52	533.4	47.7	2328		19916	32.08	221
3224	170-35-F	1.00	10200	170	30.50	790.0	17.0		"				662	55	51	570.9	50.0	2340		30519	29.79	188

(M. P. Special.) TEST OF LOCOMOTIVE NO. 387 TYPE 2-8-0 CLASS H8sb (Sheet No. 4)

SUMMARY OF AVERAGE RESULTS.

Test Number	Laboratory Designation	Pressure, Pounds per Square Inch. In Boiler. Average.	Maximum.	Minimum.	In Branch Pipe.	Air in Laboratory, Barometric.	Draft, Inches of Water. In Smoke Box. Front of Diaphragm.	Back of Diaphragm.	In Fire Box.	In Ash Pan.	Injectors. Hours in Action. Total, Right.	Total, Left.	Quality of Steam. In Dome.	In Branch Pipe.	Degrees of Superheat in Branch Pipe.	Factor of Correction	Coal, Sparks and Ash, Pounds. Coal Fired. Kind.	Total.	Per Cent. of Moisture.	Total. Dry Coal Fired.	Combustible by Analysis.	Ash by Analysis.
		217	218	219	220	221	222	223	224	225	226	227	228	229	230	231	232	233	234	235	236	237
3207	40-20-F	205.3	206	204	201.2	14.24	0.90	0.90	0.40	0.04	2.00	-	99.48	-	97.32	0.9963	Bituminous	2000	2.24	1955	1829	127
3210	40-30-F	205.3	206	203	202.1	14.30	1.50	1.30	0.30	0.08	2.00	6	99.44	-	130.64	0.9960	"	3000	2.24	2933	2774	191
3246	40-75-F	206.0	206	206	200.0	14.27	5.40	5.50	1.70	0.10	0.50	-	99.45		170.79	0.9961	"	1810	3.00	1756	1622	166
3247	40-88-F	206.0	206	206	200.7	14.26	6.20	6.40	2.10	0.12	0.25	-	99.33	-	171.32	0.9953	"	1542	3.00	1496	1382	142
3205	50-20-F	205.8	206	205	201.2	14.04	1.30	1.10	0.40	0.13	0.75	-	99.46		101.20	0.9962	"	1125	2.24	1100	1040	72
3206	60-20-F	205.9	206	205	201.7	14.24	1.10	1.00	0.30	0.17	1.75	-	99.38		108.92	0.9956	"	2437	2.24	2382	2253	155
3209	60-30-F	206.0	206	206	201.5	14.38	2.00	1.80	0.70	0.10	1.50	-	99.46		130.05	0.9962	"	3120	2.24	3050	2885	199
3227	60-35-F	206.0	206	206	201.2	13.90	2.30	2.10	1.00	0.80	1.50	-	99.48		134.96	0.9963	"	3613	2.61	3519	3074	492
3242	60-68-F	206.0	206	206	198.5	14.26	6.00	6.10	2.20	0.11	0.50	-	99.43		172.90	0.9960	"	3000	3.00	2910	2688	276
3245	60-75-F	203.3	206	199	194.7	14.27	7.80	7.90	2.80	0.10	0.50	-	99.38		165.71	0.9956	"	4000	3.00	3880	3584	368
3244	60-86-F	195.0	206	187	186.0	14.23	8.10	7.90	2.60	0.17	0.25	0	99.46		182.01	0.9962	"	1752	3.00	1699	1570	161
3201	80-20-F	205.8	206	205	202.4	14.13	1.70	1.50	0.70	0.05	2.00	-	99.52		125.59	0.9966	"	3736	2.24	3652	3455	238
3202	80-30-F	205.3	206	202	202.0	14.11	2.40	2.10	0.90	0.09	1.50	-	99.54		132.76	0.9968	"	3819	2.24	3733	3531	243
3203	80-40-F	206.0	207	205	201.5	14.06	3.00	2.80	0.90	0.13	0.50	-	99.54		144.98	0.9968	"	1500	2.24	1466	1387	96
3204	80-40-F	205.5	206	204	199.4	13.99	3.20	2.80	0.80	0.15	1.75	-	99.41		152.14	0.9958	"	5708	2.24	5580	5278	364
3238	80-55-F	206.0	206	206	200.0	14.21	5.40	5.20	2.30	0.10	0.50	-	99.48		179.32	0.9963	"	3000	2.61	2922	2552	409
3239	80-58-F	204.9	206	203	196.7	14.20	6.10	5.90	2.70	0.12	1.00	-	99.45		194.54	0.9961	"	6170	2.61	6015	5254	842
3241	80-63-F	204.7	206	200	195.9	14.22	6.70	6.40	2.20	0.17	1.00	-	99.47		210.25	0.9963	"	5282	2.61	5144	4493	720
3208	100-25-F	206.3	208	206	200.8	14.20	2.40	2.30	0.90	0.10	1.00	-	99.52		157.0	0.9966	"	2500	2.24	2444	2312	159
3211	100-25-F	205.8	206	205	201.0	14.23	2.60	2.30	1.10	0.18	0.50	-	99.51		157.41	0.9965	"	1500	2.24	1466	1387	96
3212	100-25-F	205.5	206	204	200.8	14.08	2.30	2.10	0.90	0.11	2.00	-	99.49		154.25	0.9964	"	5000	2.24	4888	4624	319
3213	100-40-F	203.3	206	200	197.3	14.04	4.50	4.20	2.00	0.25	0.50	-	99.64		155.46	0.9975	"	2070	2.24	2024	1914	132
3214	100-40-F	202.3	206	187	195.4	14.35	4.00	3.70	1.60	0.18	2.00	0	99.39		176.20	0.9957	"	3409	2.04	8237	7247	1090
3215	100-45-F	204.5	206	199	196.2	14.13	5.10	4.80	2.10	0.27	2.00	-	99.46		179.67	0.9962	"	9810	2.04	9610	8454	1271
3236	100-50-F	205.4	206	204	196.6	14.04	5.80	5.60	2.20	0.15	1.00	-	99.45		200.64	0.9961	"	5000	2.06	4897	4174	790
3237	100-55-F	203.4	206	20	194.6	14.19	6.2	6.0	2.3	0.13	2.00		99.44		185.38	0.9960	"	6000	2.61	5843	5104	818
3223	120-20-F	206.0	206	206	201.1	13.98	2.0	1.9	0.8	0.07	2.00		99.51		126.77	0.9965	"	4379	2.04	4290	3774	568
3221	120-30-F	205.9	206	205	199.8	14.05	3.7	3.5	1.7	0.22	2.00		99.53		155.56	0.9967	"	7000	2.04	6857	6033	907
3230	120-40-F	204.3	206	200	195.3	14.04	5.1	4.9	2.2	0.23	2.00		99.44		188.46	0.9960	"	9712	2.61	9459	8252	1324
3216	120-50-F	186.1	206	169	176.3	14.14	6.30	5.8	2.5	0.38	1.00		99.50		192.52	0.9964	"	5890	2.04	5770	5076	763
3217	120-50-F	198.0	206	193	187.0	14.04	6.60	6.2	2.5	0.50	0.75		99.49		196.48	0.9964	"	4800	2.04	4702	4138	622
3225	140-25-F	205.6	206	204	199.4	14.26	3.20	3.2	1.2	0.12	1.50		99.49		176.34	0.9964	"	5000	2.61	4870	4254	682
3218	140-35-F	198.3	206	175	190.5	14.09	5.50	5.3	2.8	0.48	2.00		99.41		162.70	0.9958	"	10407	2.04	10195	8969	1349
3220	140-40-F	204.9	206	200	196.0	14.04	5.90	5.7	2.3	0.31	1.00		99.58		168.88	0.9970	"	5410	2.04	5300	4662	701
3229	160-30-F	204.9	206	202	197.7	14.05	4.60	4.4	2.1	0.22	2.00		99.44		182.10	0.9960	"	8480	2.61	8259	7214	1156
3222	160-35-F	203.3	205	202	194.7	13.87	5.90	5.6	2.6	0.28	1.00		99.42		167.47	0.9959	"	5207	2.04	5101	4487	675
3235	160-40-F	198.7	206	193	189.1	14.07	6.40	6.3	2.7	0.27	1.00		99.48		193.93	0.9963	"	5702	2.06	5585	4760	900
3228	170-20-F	205.8	206	205	200.3	13.94	2.09	2.7	1.5	0.13	2.00		99.48		145.70	0.9963	"	6000	2.61	5843	5104	818
3224	170-35-F	204.1	206	202	195.4	14.28	5.80	5.6	2.4	0.31	1.00		99.45		185.03	0.9961	"	5000	2.61	4870	4254	682

(M. P. Special.) TEST OF LOCOMOTIVE No. 387 TYPE 2-8-0 CLASS Heeb SHEET No. 8)

SUMMARY OF AVERAGE RESULTS.

Test Number	Laboratory Designation	COAL, SPARKS AND ASH, LBS. TOTAL: Cinders Collected in Smoke Box	Sparks Discharged From Stack	Cinders and Sparks	ANALYSIS OF COAL, PER CENT.: Fixed Carbon	Volatile Matter	Moisture	Ash	Sulphur, Determined Separately			CALORIFIC VALUE PER LB. OF FUEL, B. T. U.: Of Dry Coal	Of Combustible	Of Cinders and Sparks			ANALYSIS OF SMOKE BOX GASES, PER CENT.: Oxygen O	Carbon Monoxide CO	Carbon Dioxide CO_2	Nitrogen N		Average Smoke in Percent
		238	239	240	241	242	243	244	245	246	247	248	249	250	251	252	253	254	255	256	257	258
3207	40-20-F				58.58	33.89	1.16	6.37	1.12			14661	15671				4.5	0.0	11.8	83.6		6
3210	40-30-F				58.58	33.89	1.16	6.37	1.12			14661	15671				4.6	0.3	13.2	81.9		12
3246	40-75-F				58.02	31.59	1.20	9.19	1.44			14140	15590				2.2	2.0	14.4	81.4		26
3247	40-88-F				58.02	31.59	1.20	9.19	1.44			14140	15590				2.4	2.4	14.0	81.6		42
3205	60-20-F				58.58	33.89	1.16	6.37	1.12			14661	15671				3.7	0.1	13.9	82.3		10
3206	60-20-F				58.58	33.89	1.16	6.37	1.12			14661	15671				4.2	0.2	13.0	82.6		10
3209	60-30-F				58.58	33.89	1.16	6.37	1.12			14661	15671				2.6	0.3	15.0	82.2		14
3227	60-35-F				54.61	30.46	1.30	13.63	3.26			13330	15466				2.1	0.5	14.9	82.4		14
3243	60-68-F				58.02	31.59	1.20	9.19	1.44			14140	15590				5.2	1.0	12.6	81.2		36
3245	60-75-F				58.02	31.59	1.20	9.19	1.44			14140	15590				6.2	1.4	11.6	80.8		42
3244	60-86-F				58.02	31.59	1.20	9.19	1.44			14140	15590				3.6	2.0	13.2	81.2		44
3201	80-20-F				58.58	33.89	1.16	6.37	1.12			14661	15671				4.9	0.3	13.3	81.5		14
3202	80-30-F				58.58	33.89	1.16	6.37	1.12			14661	15671				2.8	0.7	14.4	82.1		12
3203	80-40-F				58.58	33.89	1.16	6.37	1.12			14661	15671				4.2	0.2	13.6	82.0		20
3204	80-40-F				58.58	33.89	1.16	6.37	1.12			14661	15671				3.3	0.3	13.9	82.4		18
3238	80-55-F				54.61	30.46	1.30	13.63	3.26			13330	15466				6.5	2.3	11.8	79.4		30
3239	80-58-F				54.61	30.46	1.30	13.63	3.26			13330	15466				5.3	1.9	12.3	80.5		30
3241	80-63-F				54.61	30.46	1.30	13.63	3.26			13330	15466				6.3	0.5	12.3	80.9		30
3208	100-25-F				58.58	33.89	1.16	6.37	1.12			14661	15671				1.9	0.5	13.6	84.3		8
3211	100-25-F				58.58	33.89	1.15	6.37	1.12			14661	15671				1.8	0.4	15.2	82.6		14
3212	100-25-F				58.58	33.89	1.16	6.37	1.12			14661	15671				1.8	0.4	15.7	82.4		14
3213	100-40-F				58.58	33.89	1.16	6.37	1.12			14661	15671				0.2	1.4	15.8	82.6		22
3214	100-40-F				54.79	31.39	0.86	12.96	1.43			13843	15925				0.8	1.0	15.2	82.9		20
3215	100-45-F				54.79	31.39	0.86	12.96	1.43			13843	15925				0.3	1.5	15.4	82.9		22
3236	100-50-F				54.61	30.46	1.30	13.63	3.26			13330	15466				0.6	0.7	17.3	81.4		34
3237	100-55-F				54.61	30.46	1.30	13.63	3.26			13330	15466				0.5	1.3	17.1	81.1		30
3223	120-20-F				54.79	31.39	0.86	12.96	1.43			13843	15925				0.3	0.2	15.8	83.7		10
3221	120-30-F				54.79	31.39	0.86	12.96	1.43			13843	15925				0.2	0.8	16.5	82.5		14
3230	120-40-F				54.61	30.46	1.30	13.63	3.26			13330	15466				3.2	1.0	14.5	81.2		20
3216	120-50-F				54.79	31.39	0.86	12.96	1.43			13843	15925				0.3	1.3	15.9	81.5		30
3217	120-50-F				54.79	31.39	0.86	12.96	1.43			13843	15925				0.3	2.6	15.5	81.6		30
3225	140-25-F				54.61	30.46	1.30	13.63	3.26			13330	15466				0.4	0.6	16.4	82.6		18
3218	140-35-F				54.79	31.39	0.86	12.96	1.43			13843	15925					Sample	Lost			34
3220	140-40-F				54.79	31.39	0.86	12.96	1.43			13843	15925				0.3	1.3	16.3	82.1		26
3229	160-30-F				54.61	30.46	1.30	13.63	3.26			13330	15466				2.2	1.2	15.8	80.8		16
3222	160-35-F				54.79	31.39	0.86	12.96	1.43			13843	15925				0.9	2.3	16.5	80.3		34
3235	160-40-F				54.61	30.46	1.30	13.63	3.26			13330	15466				0.6	2.3	17.3	79.9		28
3228	170-20-F				54.61	30.46	1.30	13.63	3.26			13330	15466				0.5	0.8	16.6	82.2		14
3224	170-35-F				54.61	30.46	1.30	13.63	3.26			13330	15466				0.7	1.3	17.2	80.9		20

(M. P. Special.) TEST OF LOCOMOTIVE NO. 387 TYPE 2-8-0 CLASS H8sb (Sheet No. 6)

SUMMARY OF AVERAGE RESULTS.

Test Number	Laboratory Designation	Water, in Pounds: Delivered to Injectors	Water, in Pounds: Lost From Boiler	Lost From	Lost From	Lost Total	Delivered to Boiler and Presumably Evaporated	Dynamometer Pull in Pounds: Average	Maximum	Minimum	Events of Stroke from Indicator Cards: Cut-off, per cent. of stroke: High Pressure Cylinder: Right Side Head End	Right Side Crank End	Left Side Head End	Left Side Crank End	Low Pressure Cylinder: Right Side Head End	Right Side Crank End	Left Side Head End	Left Side Crank End	Release, per cent of stroke: High Pressure Cylinder: Right Side Head End	Right Side Crank End	Left Side Head End	Left Side Crank End
		259	260	261	262	263	264	265	266	267	268	269	270	271	272	273	274	275	276	277	278	279
3207	40-20-F	18687					18687	16331	16956	16170	22.1	22.9	18.4	19.2					60.8	56.7	56.8	55.5
3210	40-30-F	25991					25991	24524	25072	23620	32.8	34.2	29.8	30.8					70.5	65.6	67.8	65.2
3246	40-75-F	13133					13133	45855	46078	45484	76.6	72.9	78.4	71.4					91.6	86.4	90.4	86.0
3247	40-88-F	7444					7441	49872	50136	49443	91.3	86.5	89.7	84.5					97.0	92.2	94.3	92.3
3205	60-20-F	9558					9558	16221	16808	15776	22.2	23.9	22.4	19.1					61.8	59.8	59.4	56.1
3206	60-20-F	21186					21186	15653	16014	15170	22.1	24.1	21.1	20.5					61.3	58.8	57.9	55.2
3209	60-30-F	24741					24741	23480	23920	21971	33.7	35.2	31.9	32.2					71.4	66.6	67.3	63.5
3227	60-35-F	28506					28506	26323	27082	25323	35.3	37.3	35.6	32.8					72.4	69.7	71.6	65.3
3242	60-68-F	15441					15441	41815	42088	41194	72.4	68.3	73.0	63.3					87.0	83.7	88.1	82.0
3245	60-75-F	15924					15924	42865	43789	41990	78.0	72.3	78.5	70.5					91.0	85.5	88.8	85.8
3244	60-86-F	8444					8444	44284	46576	42590	90.3	83.5	88.7	82.5					93.7	91.5	93.7	91.7
3201	80-20-F	29247					29247	14050	15121	12882	24.2	27.5	21.2	22.2					60.0	60.1	58.0	56.6
3202	80-30-F	29654					29654	22695	23570	21722	33.8	37.3	31.6	35.5					69.1	69.2	68.6	65.8
3203	80-40-F	12108					12108	27562	27638	27486	43.1	44.0	39.5	41.9					74.9	73.8	72.9	70.6
3204	80-40-F	41243					41243	28053	28908	27435	46.3	42.6	42.3	39.9					76.3	71.2	72.8	68.2
3238	80-55-F	14959					14959	33847	34316	33326	53.3	51.5	53.9	48.3					81.9	76.0	79.1	73.9
3239	80-58-F	31606					31606	36898	37129	36712	61.1	56.1	59.4	54.0					85.8	77.9	82.3	75.1
3241	80-63-F	33955					33955	37502	37599	37338	66.1	61.4	66.9	59.0					86.2	80.4	83.4	79.1
3208	100-25-F	20757					20757	18670	18840	18444	33.0	33.1	29.1	30.0					66.9	63.7	65.4	62.2
3211	100-25-F	10479					10479	18630	18791	18493	31.8	31.3	30.5	29.8					69.5	64.3	67.0	65.5
3212	100-25-F	40087					40087	19542	19782	19187	30.7	32.7	29.8	28.7					67.2	64.3	66.1	63.3
3213	100-40-F	13455					13455	25788	26429	24720	43.6	43.5	42.9	40.3					77.6	71.1	73.3	70.1
3214	100-40-F	52635					52635	25957	26731	24170	43.3	41.5	41.9	39.7					76.8	70.5	73.7	69.8
3215	100-45-F	57197					57197	28373	29111	26781	46.6	44.8	46.3	43.8					78.6	72.1	74.9	71.5
3236	100-50-F	30959					30959	31518	31981	30952	50.8	50.3	51.4	47.7					77.6	74.9	77.6	72.4
3237	100-55-F	32556					32556	33141	33430	32911	55.1	51.6	53.4	50.3					80.6	74.9	77.2	73.9
3228	120-20-F	35877					35877	13348	13970	12196	24.7	25.0	24.0	20.9					60.6	60.5	60.6	56.2
3221	120-30-F	49513					49513	19779	20428	18495	35.9	34.5	32.7	32.6					71.1	67.7	67.3	65.3
3230	120-40-F	58521					58521	24645	25574	23270	42.2	41.5	42.9	40.2					75.8	71.2	74.1	69.0
3216	120-50-F	31621					31621	25758	28298	23320	52.3	49.3	52.6	47.9					78.6	74.7	77.9	73.3
3217	120-50-F	24766					24766	27184	27641	26479	52.5	48.4	53.2	47.0					79.3	75.3	79.2	73.9
3225	140-25-F	35778					35778	15884	16758	14420	31.7	31.5	27.4	27.2					68.8	66.8	66.2	63.7
3210	140-35-F	57104					57104	20131	20926	17898	39.3	37.8	36.3	36.5					74.1	70.3	71.2	67.4
3220	140-40-F	31681					31681	22791	23420	22070	41.8	42.3	42.0	39.7					74.7	73.7	73.9	69.9
3229	160-30-F	55730					55730	16628	17204	15568	37.4	32.9	32.3	33.6					71.5	69.5	70.3	67.5
3222	160-35-F	30244					30244	18515	19088	17849	41.6	37.4	36.2	36.3					74.9	70.4	70.2	67.9
3235	160-40-F	32666					32666	19924	20428	19435	43.8	42.1	42.1	41.2					76.1	72.2	75.4	71.6
3226	170-20-F	40422					40422	9723	10324	8780	25.1	24.1	22.2	18.0					64.3	62.8	62.4	58.3
3224	170-35-F	30826					30826	17855	18444	16708	41.0	38.2	36.7	38.4					73.4	70.8	71.1	69.5

(M. P. Special.) TEST OF LOCOMOTIVE No. 387 TYPE 2-8-0 CLASS Hsb (Sheet No. 7)

SUMMARY OF AVERAGE RESULTS.

Test Number	Laboratory Designation	EVENTS OF STROKE FROM INDICATOR CARDS												PRESSURE FROM INDICATOR CARDS								Factor of Evaporation
		RELEASE, PER CENT. OF STROKE				BEGINNING OF COMPRESSION, PER CENT. OF STROKE								INITIAL PRESSURES, POUNDS PER SQUARE INCH								
		LOW PRESSURE CYLINDER				HIGH PRESSURE CYLINDER				LOW PRESSURE CYLINDER				HIGH PRESSURE CYLINDER				LOW PRESSURE CYLINDER				
		RIGHT SIDE		LEFT SIDE		RIGHT SIDE		LEFT SIDE		RIGHT SIDE		LEFT SIDE		RIGHT SIDE		LEFT SIDE		RIGHT SIDE		LEFT SIDE		
		Head End	Crank End	Head End	Crank End	Head End	Crank End	Head End	Crank End	Head End	Crank End	Head End	Crank End	Head End	Crank End	Head End	Crank End	Head End	Crank End	Head End	Crank End	
		280	281	282	283	284	285	286	287	288	289	290	291	292	293	294	295	296	297	298	299	300
3207	40-20-F													193.3	197.4	199.4	191.8					1.2769
3210	40-30-F													195.2	204.4	196.9	201.4					1.2961
3246	40-75-F													198.3	199.5	198.0	206.0					1.3177
3247	40-88-F													199.7	200.0	198.0	204.7					1.3182
3205	60-20-F													191.3	196.8	193.8	193.7					1.2865
3206	60-20-F													190.9	196.5	197.0	192.0					1.2879
3209	60-30-F													200.2	199.6	197.2	203.2					1.2933
3227	60-35-F													199.1	202.6	198.0	200.9					1.2918
3242	60-68-F													197.3	200.0	194.0	203.0					1.3196
3245	60-75-F													192.3	194.3	191.3	198.0					1.3140
3244	60-86-F													185.3	185.7	181.3	187.0					1.3212
3201	80-20-F													179.1	205.5	194.8	204.5					1.2986
3202	80-30-F													187.7	204.3	191.4	207.1					1.3021
3203	80-40-F													196.5	203.3	192.8	203.8					1.3095
3204	80-40-F													192.1	201.2	197.2	199.9					1.3126
3238	80-55-F													195.8	200.0	194.0	200.5					1.3198
3239	80-58-F													190.4	195.7	188.4	194.4					1.3292
3241	80-63-F													192.0	194.7	187.1	196.6					1.3378
3208	100-25-F													193.8	197.2	197.7	193.7					1.3130
3211	100-25-F													192.3	196.8	193.5	195.8					1.3065
3212	100-25-F													190.0	197.4	191.3	198.0					1.3115
3213	100-40-F													189.8	195.3	190.0	194.3					1.3113
3214	100-40-F													188.5	195.2	189.0	192.5					1.3207
3215	100-45-F													192.8	198.4	191.5	197.2					1.3208
3236	100-50-F													193.0	197.9	189.3	200.4					1.3305
3237	100-55-F													191.0	195.4	187.9	193.3					1.3250
3223	120-20-F													182.0	192.3	191.8	192.5					1.2926
3221	120-30-F													182.5	194.1	188.7	192.5					1.3083
3230	120-40-F													182.6	193.6	187.3	189.9					1.3230
3216	120-50-F													171.6	176.6	167.3	177.3					1.3266
3217	120-50-F													179.8	186.8	178.8	187.4					1.3162
3225	140-25-F													176.8	189.2	185.6	182.8					1.3209
3218	140-35-F													172.9	185.7	178.4	183.5					1.3126
3220	140-40-F													181.7	193.1	182.6	191.7					1.3142
3229	160-30-F													173.9	188.5	181.8	179.1					1.3233
3222	160-35-F													173.7	185.0	178.1	182.6					1.3114
3235	160-40-F													174.1	180.1	174.7	175.0					1.3239
3228	170-20-F													170.8	185.6	186.2	175.0					1.3051
3224	170-35-F													174.0	183.1	177.1	178.6					1.3216

(M. P Special.) TEST OF LOCOMOTIVE No. 367 TYPE 2-8-0 CLASS H8sb (Sheet No. 8

SUMMARY OF AVERAGE RESULTS.

Test Number	Laboratory Designation	PRESSURES FROM INDICATOR CARDS: Steam Chest Pressures, Pounds per Square Inch: High Pressure: Right Side	High Pressure: Left Side	Low Pressure: Right Side	Low Pressure: Left Side		Pressures at Cut-off, Pounds per Square Inch: High Pressure Cylinder: Right Side: Head End	H.P. Right Side: Crank End	H.P. Left Side: Head End	H.P. Left Side: Crank End	Low Pressure Cylinder: Right Side: Head End	L.P. Right Side: Crank End	L.P. Left Side: Head End	L.P. Left Side: Crank End	Pressures at Release, Pounds per Square Inch: High Pressure Cylinder: Right Side: Head End	H.P. Right Side: Crank End	H.P. Left Side: Head End	H.P. Left Side: Crank End	Low Pressure Cylinder: Right Side: Head End	L.P. Right Side: Crank End	L.P. Left Side: Head End	L.P. Left Side: Crank End
		301	302	303	304	305	306	307	308	309	310	311	312	313	314	315	316	317	318	319	320	321
3207	40-20-F		201.9				154.1	159.9	158.4	158.5					56.4	64.3	55.8	56.9				
3210	40-30-F		203.8				167.1	176.4	164.8	171.7					72.0	89.7	68.2	75.8				
3246	40-75-F		197.5				186.3	185.0	184.3	190.8					155.0	149.8	154.8	152.8				
3247	40-88-F		197.7				192.7	188.7	191.0	196.3					180.7	173.0	178.7	177.0				
3205	60-20-F		203.2				145.8	152.2	139.2	150.3					53.0	59.8	49.2	58.3				
3206	60-20-F		203.5				139.1	143.6	136.2	151.0					50.8	58.4	49.9	49.8				
3209	60-30-F		202.7				155.9	161.8	149.5	154.2					65.6	77.8	63.7	72.9				
3227	60-35-F		200.7				158.9	163.2	155.6	166.1					74.0	82.3	69.1	79.9				
3242	60-68-F		196.8				171.3	169.8	164.8	171.8					135.8	124.0	130.5	126.5				
3245	60-75-F		189.3				176.3	169.0	169.7	173.3					146.3	136.7	143.7	137.3				
3244	60-86-F		181.0				171.0	168.3	166.0	172.7					161.0	152.0	154.7	153.0				
3201	80-20-F		202.8				114.6	135.9	124.2	129.7					44.5	59.8	42.5	51.0				
3202	80-30-F		201.1				133.1	153.8	131.9	140.7					60.9	74.2	54.0	70.1				
3203	80-40-F		205.5				146.3	157.5	141.0	150.8					77.0	85.5	67.3	81.0				
3204	80-40-F		200.8				141.7	154.4	143.8	150.5					77.2	85.1	73.8	80.4				
3238	80-55-F		195.8				158.8	158.0	151.8	163.0					95.5	100.0	95.5	99.0				
3239	80-58-F		193.3				161.0	164.7	158.1	167.0					110.3	111.4	106.1	113.9				
3241	80-63-F		191.9				169.3	160.9	157.0	169.0					122.4	115.0	118.9	116.7				
3208	100-25-F		201.5				120.8	130.8	130.2	124.5					55.0	60.2	52.7	54.7				
3211	100-25-F		200.3				125.5	138.5	128.3	124.0					55.0	62.0	52.8	51.0				
3212	100-25-F		200.9				126.5	132.9	126.2	131.5					53.0	61.4	50.5	54.2				
3213	100-40-F		197.3				138.0	142.3	133.8	142.3					69.3	78.8	69.5	73.8				
3214	100-40-F		194.1				137.3	145.4	133.8	142.6					69.5	79.4	67.3	72.8				
3215	100-45-F		195.2				143.1	149.1	139.5	145.0					76.7	86.0	78.3	80.8				
3236	100-50-F		193.7				146.6	151.1	143.1	147.9					90.3	95.1	87.1	89.9				
3237	100-55-F		190.6				147.0	154.9	145.3	150.1					91.1	99.4	93.4	95.3				
3223	120-20-F		197.3				107.0	123.5	112.8	109.0					43.0	49.0	41.1	39.8				
3221	120-30-F		198.4				120.1	136.3	124.5	123.5					55.0	63.1	52.8	55.8				
3230	120-40-F		194.7				128.5	139.0	128.5	129.1					64.2	74.2	66.5	67.3				
3216	120-50-F		173.7				123.4	131.1	121.0	127.1					74.9	80.1	73.3	75.6				
3217	120-50-F		183.6				131.2	141.6	128.0	136.2					80.2	83.8	77.0	79.6				
3225	140-25-F		199.1				111.6	125.4	119.5	117.4					47.3	53.2	43.4	46.9				
3218	140-35-F		190.4				117.2	126.0	117.0	119.8					55.7	61.7	51.1	57.9				
3220	140-40-F		194.4				129.7	133.4	121.1	126.9					66.2	68.7	60.1	65.3				
3229	160-30-F		195.7				108.6	126.9	120.5	106.1					51.2	53.5	45.5	46.8				
3222	160-35-F		192.0				109.9	125.7	113.7	112.6					53.3	59.4	57.0	53.3				
3235	160-40-F		186.6				118.0	119.0	109.7	111.9					61.6	61.1	52.3	56.7				
3228	170-20-F		200.9				101.5	112.8	107.7	104.2					37.1	41.0	35.1	31.1				
3224	170-35-F		192.4				110.1	121.3	113.6	105.9					54.3	57.3	52.3	51.1				

(M. P. Special.) TEST OF LOCOMOTIVE No. 387 TYPE 2-8-0 CLASS Bsb (Sheet No. 9.)

		SUMMARY OF AVERAGE RESULTS.																SUMMARY OF AVERAGE RESULTS, BOILER.					
		PRESSURES FROM INDICATOR CARDS																DRY COAL FIRED		EVAPORATION, POUNDS			
		PRESSURES AT BEGINNING OF COMPRESSION, POUNDS PER SQUARE INCH								LEAST BACK PRESSURE, POUNDS PER SQUARE INCH										STEAM PER HOUR			
		HIGH PRESSURE CYLINDER				LOW PRESSURE CYLINDER				HIGH PRESSURE CYLINDER				LOW PRESSURE CYLINDER									
Test	Laboratory	RIGHT SIDE		LEFT SIDE		RIGHT SIDE		LEFT SIDE		RIGHT SIDE		LEFT SIDE		RIGHT SIDE		LEFT SIDE		Per	Per Square Foot of Grate			Per Sq. Ft. of Heating	Steam Per Pound of Dry
Number	Designation	Head End	Crank End	Head End	Crank End	Head End	Crank End	Head End	Crank End	Head End	Crank End	Head End	Crank End	Head End	Crank End	Head End	Crank End	Hour	Surface	Moist	Superheated	Surface	Coal Fired
		322	323	324	325	326	327	328	329	330	331	332	333	334	335	336	337	339	339	340	341	342	343
3207	40-20-F									0.5	0.2	0.2	0.5					978	17.67	9339	9304	2.65	9.51
3210	40-30-F									1.1	-	1.0	0.7					1467	26.51	12996	12944	3.56	8.82
3246	40-75-F									1.3	3.0	1.0	1.3					3512	63.46	26266	26164	7.40	7.45
3247	40-88-F									1.0	3.3	1.0	1.0					5984	108.13	29764	29624	8.38	4.95
3205	60-20-F									1.3	1.0	0.7	0.3					1467	26.51	12744	12696	3.59	8.65
3206	60-20-F									0.9	1.1	0.6	0.1					1361	24.59	12106	12053	3.41	8.86
3209	60-30-F									0.3	1.0	0.9	1.0					2033	36.74	16494	16451	4.65	8.08
3227	60-35-F									1.8	2.1	1.2	0.9					2346	42.39	19004	18934	5.35	8.07
3242	60-68-F									2.8	3.3	1.0	2.8					5820	105.17	30882	30758	8.70	5.28
3245	60-75-F									3.3	3.7	2.7	3.0					7760	140.22	31848	31708	8.97	4.09
3244	60-86-F									2.3	3.7	1.3	1.3					6796	122.80	33776	33648	9.51	4.95
3201	80-20-F									2.4	2.0	0.2	0.4					1826	33.0	14524	14574	4.10	8.00
3202	80-30-F									2.8	4.2	0.3	1.0					2489	44.98	19769	19705	5.57	7.92
3203	80-40-F									3.3	4.0	1.0	1.8					2932	52.98	24216	24139	6.83	8.25
3204	80-40-F									2.8	3.3	1.2	1.7					3189	57.63	23567	23486	6.64	7.36
3236	80-55-F									4.0	3.8	4.3	3.5					5844	105.60	29918	29807	8.43	5.10
3239	80-58-F									5.0	5.3	4.7	4.6					6015	108.69	31606	31483	8.90	5.23
3241	80-65-F									4.3	5.6	3.4	2.7					5144	92.95	33955	33829	9.57	6.58
3208	100-25-F									3.0	2.2	2.3	1.8					2444	44.16	20757	20684	5.85	8.46
3211	100-25-F									1.0	2.3	2.0	1.3					2932	52.98	20958	20883	5.91	7.12
3212	100-25-F									2.6	2.8	2.0	2.3					2444	44.16	20044	19972	5.65	8.17
3213	100-40-F									2.8	3.8	3.8	3.5					4048	73.13	26910	26843	7.59	6.65
3214	100-40-F									4.2	3.0	3.8	4.1					4119	74.43	26518	26205	7.41	6.36
3215	100-45-F									4.[illegible]	5.6	4.2	4.3					4805	86.83	28599	28490	8.06	5.93
3256	100-50-F									7.9	6.7	4.9	4.9					4897	88.49	30959	30838	8.72	6.30
3257	100-55-F									5.9	5.0	3.7	4.9					5843	105.58	32556	32426	9.17	5.58
3223	120-20-F									1.4	2.8	1.3	1.7					2143	38.76	17937	17876	5.05	8.38
3221	120-30-F									4.8	5.8	4.2	4.8					3429	61.96	24757	24675	6.98	7.20
3230	120-40-F									3.5	5.8	4.0	3.9					4730	85.47	29251	29144	8.24	6.16
3216	120-50-F									6.3	7.4	6.7	7.0					5770	104.26	31512	31507	8.91	5.46
3217	120-50-F									8.0	8.5	7.8	7.8					6269	113.28	33021	32902	9.30	5.25
3225	140-25-F									3.4	3.1	2.8	3.3					3247	58.67	23852	23766	6.72	7.32
3218	140-35-F									5.5	7.2	5.2	5.4					5098	92.12	28552	28432	8.04	5.58
3220	140-40-F									8.3	9.4	6.6	7.6					5300	95.77	31661	31586	8.93	5.96
3229	160-30-F									6.5	7.2	4.8	5.2					4130	74.63	27865	27784	7.85	6.72
3222	160-35-F									7.3	8.7	6.6	7.1					5101	92.18	30244	30120	8.52	5.90
3235	160-40-F									9.3	8.6	7.3	7.7					5585	100.92	32665	32545	9.20	5.83
3228	170-20-F									3.7	6.5	3.8	2.7					2922	52.80	20211	20136	5.69	6.89
3224	170-35-F									6.6	9.1	6.4	7.0					4870	88.00	30826	30706	8.68	6.31

(M. P. Special.) TEST OF LOCOMOTIVE No. 387 TYPE 2-8-0 CLASS H3sb (Sheet No. 10)

Test Number	Laboratory Designation	SUMMARY OF AVERAGE RESULTS, BOILER. Equiv't Evap'n from and at 212° F., lbs. Per Hour	Equiv't Evap'n Per Hour, Per Square Foot of Heating Surface	Equiv't Evap'n Per Pound of Coal as Fired	Equiv't Evap'n Per Pound of Dry Coal as Fired	Equiv't Evap'n Per Pound of Combustible	Boiler Horse Power	Efficiency of Boiler	SUMMARY OF AVERAGE RESULTS, ENGINES. Mean Effective Pressure, Pounds per Square Inch, High Pressure Cylinder, Right Side, Head End	M.E.P. H.P. Right Side Crank End	M.E.P. H.P. Left Side Head End	M.E.P. H.P. Left Side Crank End	M.E.P. Low Pressure Cylinder Right Side Head End	M.E.P. L.P. Right Side Crank End	M.E.P. L.P. Left Side Head End	M.E.P. L.P. Left Side Crank End	Receiver Pressure Right Side	Receiver Pressure Left Side	Number of Expansions Right Side Head End	Number of Expansions Right Side Crank End	Number of Expansions Left Side Head End	Number of Expansions Left Side Crank End
		344	345	346	347	348	349	350	351	352	353	354	355	356	357	358	359	360	361	362	363	364
3207	40-20-F	11880	3.36	11.88	12.15	12.85	344.3	80.42	79.07	80.98	71.40	70.01										
3210	40-30-F	16777	4.74	11.18	11.44	12.10	486.3	75.72	107.05	112.92	99.05	103.43										
3246	40-75-F	34476	9.75	9.52	9.82	10.65	999.3	67.39	182.32	174.20	179.88	178.91										
3247	40-82-F	39050	11.04	6.33	6.53	7.06	1131.9	44.81	190.27	182.70	184.19	188.34										
3205	60-20-F	16333	4.62	10.89	11.13	11.78	473.4	73.67	74.90	80.05	69.91	67.40										
3206	60-20-F	15525	4.39	11.15	11.41	12.06	449.9	75.52	72.39	78.60	67.20	64.46										
3209	60-30-F	21250	6.01	10.22	10.45	11.05	615.9	69.17	103.47	109.56	97.07	100.91										
3227	60-35-F	24459	6.92	10.18	10.43	11.94	709.0	75.93	112.11	114.75	105.04	106.81										
3242	60-68-F	40588	11.48	6.76	6.97	7.55	1176.5	47.83	169.39	166.86	164.74	160.47										
3245	60-75-F	41664	11.78	5.21	5.37	5.81	1207.7	36.85	168.58	162.38	167.19	167.21										
3244	60-86-F	44456	12.57	6.34	6.54	7.08	1288.6	44.88	167.28	162.42	166.37	166.30										
3201	80-20-F	18926	5.40	10.10	10.40	11.00	548.6	68.60	62.24	80.78	60.60	64.94										
3202	80-30-F	25659	7.26	10.08	10.31	10.90	743.7	68.24	91.41	106.86	87.01	99.20										
3203	80-40-F	31610	8.94	10.54	10.78	11.40	916.2	71.35	114.83	122.80	107.99	116.55										
3204	80-40-F	30804	8.71	9.44	9.66	10.21	892.9	63.94	116.34	119.85	111.76	110.20										
3238	80-55-F	39339	11.12	6.56	6.73	7.71	1140.3	48.89	137.38	137.90	131.58	130.49										
3239	80-58-F	41847	11.83	6.78	6.96	7.96	1213.0	50.67	145.11	142.67	142.10	140.39										
3241	80-63-F	45256	12.80	8.57	8.80	10.07	1311.8	64.06	157.65	146.20	149.95	149.40										
3208	100-25-F	27161	7.68	10.86	11.11	11.75	787.3	73.54	84.05	88.81	79.63	78.79										
3211	100-25-F	27284	7.72	9.10	9.31	9.84	790.9	61.62	85.21	88.86	80.91	78.17										
3212	100-25-F	26193	7.41	10.48	10.72	11.33	759.2	70.95	81.59	89.71	79.52	79.66										
3213	100-40-F	35199	9.95	8.50	8.70	9.20	1020.3	57.58	109.14	113.54	103.95	106.10										
3214	100-40-F	34609	9.79	8.23	8.40	9.55	1003.2	58.88	106.44	108.42	100.90	103.57										
3215	100-45-F	37630	10.64	7.67	7.83	8.90	1090.7	54.89	114.75	116.51	111.26	110.36										
3236	100-50-F	41030	11.60	8.21	8.36	9.83	1189.3	61.00	122.28	123.85	119.74	119.06										
3237	100-55-F	42900	12.13	7.15	7.34	8.41	1243.5	53.43	127.26	130.22	123.88	124.85										
3223	120-20-F	23107	6.53	10.55	10.77	12.25	669.8	75.51	59.61	66.06	58.83	46.93										
3221	120-30-F	32282	9.13	9.22	9.41	10.70	935.7	65.96	86.79	91.81	81.42	80.00										
3230	120-40-F	38558	10.90	7.94	8.15	9.35	1117.6	59.33	101.21	103.67	97.26	95.91										
3216	120-50-F	41797	11.82	7.10	7.24	8.23	1211.5	50.75	104.25	104.48	99.50	100.87										
3217	120-50-F	43306	12.25	6.77	6.91	7.85	1255.2	48.44	110.59	112.11	106.48	105.65										
3225	140-25-F	31393	8.88	9.42	9.67	11.07	909.9	70.40	72.35	77.81	65.89	64.40										
3218	140-35-F	37320	10.56	7.17	7.32	8.32	1081.7	51.31	93.60	99.93	90.52	89.40										
3220	140-40-F	41510	11.74	7.67	7.83	8.90	1203.2	54.89	93.60	99.95	90.52	89.40										
3229	160-30-F	36727	10.38	8.66	8.89	10.18	1064.6	64.72	77.33	77.64	71.43	68.08										
3222	160-35-F	39499	11.17	7.59	7.74	8.80	1144.9	54.26	81.51	85.23	76.92	74.23										
3235	160-40-F	43086	12.18	7.56	7.71	9.05	1248.9	56.15	87.05	87.72	79.08	80.84										
3228	170-20-F	26279	7.43	8.76	8.99	10.39	761.7	65.45	53.61	54.80	50.52	38.46										
3224	170-35-F	40581	11.47	8.12	8.33	9.54	1176.5	60.64	80.35	82.69	75.78	73.32										

(H. P. Special.) TEST OF LOCOMOTIVE No. 387 TYPE 2-8-0 CLASS H8ab (SHEET No. 11)

SUMMARY OF AVERAGE RESULTS, ENGINES.

Test Number	Laboratory Designation	INDICATED HORSE POWER — High Pressure Cylinder — Right Side — Head End	Right Side — Crank End	Left Side — Head End	Left Side — Crank End	Low Pressure Cylinder — Right Side — Head End	Right Side — Crank End	Left Side — Head End	Left Side — Crank End	DIVISION OF POWER — High Pressure Cylinder — Right Side	High Pressure Cylinder — Left Side	Low Pressure Cylinder — Right Side	Low Pressure Cylinder — Left Side	Total — Right Side	Total — Left Side	Total I.H.P.	Consumed per I. H. P., per Hour — Dry Coal, Pounds	Steam, Pounds	B. T. U.	LOCOMOTIVE — Dynamometer Horse Power	Pounds per D. H. P. per Hour — Of Dry Coal	Of Steam	B. T. U. Per D. H. P. Per Hour
		365	366	367	368	369	370	371	372	373	374	375	376	377	378	379	380	381	382	383	384	385	386
3207	40-20-F	109.72	109.52	98.53	94.32					219.24	192.85					412.09	2.37	22.12	34747	314.3	3.11	29.00	45596
3210	40-30-F	148.54	152.71	136.59	139.34					301.25	276.03					577.28	2.54	21.20	37229	472.0	3.11	25.90	45576
3246	40-75-F	252.99	235.59	248.24	241.03					448.58	489.27					977.85	3.59	24.43	50763	878.8	4.00	27.19	56560
3247	40-88-F	264.02	247.08	254.14	253.73					511.10	507.91					1019.01	5.87	27.10	83002	955.7	6.26	28.90	88516
3205	60-20-F	155.90	162.39	134.71	136.20					318.29	280.91					599.20	2.45	20.82	35919	486.3	3.13	26.64	45889
3206	60-20-F	150.67	159.45	139.10	130.26					310.12	269.36					579.50	2.35	20.47	34453	451.9	3.01	26.25	44150
3209	60-30-F	153.36	222.25	200.93	203.92					437.61	404.85					842.46	2.41	19.20	35333	677.9	3.00	23.81	43983
3227	60-35-F	233.35	232.78	217.43	215.84					466.13	433.27					899.40	2.61	20.72	34791	760.0	3.09	24.52	41190
3242	60-68-F	352.57	318.20	341.01	324.28					670.77	665.29					1336.06	4.36	21.85	61650	1202.8	4.84	24.29	68438
3245	60-75-F	350.88	329.41	346.09	337.90					680.29	683.99					1364.28	5.69	23.03	80457	1232.2	6.30	25.50	89082
3244	60-86-F	348.17	329.48	344.39	336.06					677.65	680.45					1358.10	5.00	24.64	70700	1273.0	5.34	26.29	75506
3201	80-20-F	172.73	218.50	167.26	174.98					391.23	342.24					733.47	2.50	19.00	36506	549.0	3.38	25.75	49554
3202	80-30-F	253.68	289.03	240.14	267.29					542.71	507.43					1050.14	2.37	18.56	34747	873.7	2.85	22.31	41784
3203	80-40-F	318.68	332.18	298.06	314.03					650.85	612.09					1262.92	2.32	18.92	34014	1061.0	2.76	22.51	40464
3204	80-40-F	322.86	324.17	308.46	296.92					647.03	605.38					1252.41	2.55	18.57	37386	1079.9	2.95	21.54	43350
3238	80-55-F	381.26	372.99	363.16	351.59					754.25	714.75					1469.00	3.98	19.73	53053	1297.3	4.50	22.34	59985
3239	80-58-F	404.38	385.90	392.20	378.26					790.28	770.46					1560.70	3.85	19.90	51521	1414.2	4.25	21.96	56653
3241	80-63-F	437.51	395.44	413.86	402.54					832.95	816.40					1649.40	3.12	20.40	41590	1437.4	3.58	23.40	47721
3208	100-25-F	291.57	300.27	274.72	265.36					591.84	540.08					1131.92	2.16	18.11	31668	898.4	2.72	22.82	39878
3211	100-25-F	295.59	300.44	279.14	263.28					596.03	542.42					1138.45	2.58	18.10	37825	896.5	3.27	22.95	47941
3212	100-25-F	283.04	303.31	274.34	268.29					586.35	542.63					1129.0	2.16	17.43	31686	940.4	2.60	20.93	38119
3213	100-40-F	387.61	383.88	358.56	357.34					762.49	715.90					1478.4	2.74	17.98	40171	1240.9	3.26	21.42	47795
3214	100-40-F	369.24	366.57	348.11	348.82					735.81	696.93					1432.7	2.87	18.08	39729	1249.1	3.30	20.74	45582
3215	100-45-F	398.07	393.92	383.85	371.69					791.99	755.54					1547.5	3.11	18.29	43052	1365.3	3.52	20.73	48727
3236	100-50-F	424.19	418.74	413.10	400.99					842.93	814.09					1657.0	2.96	18.50	39457	1516.6	3.23	20.21	43056
3237	100-55-F	441.46	440.27	427.39	420.49					881.73	847.88					1729.6	3.38	18.61	45055	1587.8	3.68	20.27	49054
3223	120-20-F	248.15	268.02	243.55	197.76					516.17	441.31					957.5	2.24	18.39	31008	770.8	2.78	22.84	38484
3221	120-30-F	361.28	372.49	337.06	323.33					733.77	660.41					1394.2	2.46	17.50	34054	1142.1	3.00	21.36	41529
3230	120-40-F	421.32	420.61	402.66	387.62					841.93	790.28					1632.2	2.90	17.74	38657	1423.1	3.32	20.35	44256
3216	120-50-F	433.97	423.90	411.94	407.68					857.87	819.62					1677.5	3.44	18.68	47620	1487.4	3.88	21.07	53711
3217	120-50-F	460.37	454.85	440.83	427.00					915.22	867.83					1783.1	3.52	18.36	48727	1569.7	3.99	20.85	55234
3225	140-25-F	351.37	368.31	317.86	303.66					719.68	621.52					1341.6	2.42	17.55	32259	1070.1	3.03	22.00	40390
3218	140-35-F	408.93	417.26	385.48	377.12					826.19	762.60					1588.8	3.21	17.78	44436	1356.2	3.76	20.83	52050
3220	140-40-F	454.58	473.00	437.21	421.54					927.58	858.75					1786.3	2.97	17.58	41114	1535.4	3.45	20.45	47758
3229	160-30-F	429.22	420.00	349.29	366.86					849.22	761.15					1610.4	2.56	17.07	34125	1280.2	3.23	21.47	43056
3222	160-35-F	452.42	461.06	424.59	400.02					913.48	824.61					1738.1	2.93	17.22	40560	1425.5	3.58	21.00	49558
3235	160-40-F	483.17	474.53	436.53	435.63					957.70	872.16					1829.9	3.05	17.66	40657	1534.0	3.64	21.07	48521
3228	170-20-F	316.15	314.98	296.29	220.20					631.13	516.49					1147.6	2.55	17.35	35992	795.4	3.67	25.04	48921
3224	170-35-F	473.84	475.27	444.45	419.80					949.11	846.25					1815.4	2.69	16.85	35858	1459.0	3.34	20.92	44522

(M. P. Special.) TEST OF LOCOMOTIVE No. 387 TYPE 2-8-0 CLASS H8b (SHEET NO 12)

SUMMARY OF AVERAGE RESULTS, LOCOMOTIVE.

Test Number	Laboratory Designation	LOCOMOTIVE: Per One Million Foot Pounds at Draw-Bar: Dry Coal, Pounds	Steam, Pounds	B. T. U.	I. H. P. per Square Foot of: Heating Surface	Grate Surface	D. H. P. per Square Foot of: Heating Surface	Grate Surface	Tractive Power Based on M. E. P., Pounds	Machine Friction of Locomotive in Terms of: Horse Power	M. E. P. Pounds	Draw-Bar Pull, Pounds	Machine Efficiency of Locomotive, Per Cent.	Efficiency of Locomotive, Per Cent.	RATIOS: Total Weight of Locomotive to Maximum I H P	Total Heating Surface to Maximum I. H. P.						
		387	388	389	390	391	392	393	394	395	396	397	398	399	400	401	402	403	404	405	406	407
3207	40-20-F	1.57	14.66	23018	0.12	7.45	0.89	5.68	21408	97.8	17.89	5081	76.27	5.58								
3210	40-30-F	1.58	13.13	23164	0.16	10.43	0.133	8.63	30124	105.3	19.26	5495	81.76	5.58								
3246	40-75-F	2.02	13.73	28563	0.28	17.67	0.248	15.88	51026	99.1	18.13	5171	89.87	4.50								
3247	40-88-F	3.16	14.60	44682	0.29	18.41	0.270	17.27	53175	63.3	11.58	3303	93.79	2.88								
3205	60-20-F	1.58	13.46	23164	0.17	10.83	0.132	8.46	20783	130.9	15.96	4534	78.15	5.55								
3206	60-20-F	1.52	13.26	22285	0.16	10.47	0.128	8.17	20070	127.6	15.56	4419	77.98	5.77								
3209	60-30-F	1.52	12.08	22285	0.24	15.22	0.192	12.25	29308	164.6	20.07	5726	80.46	5.79								
3227	60-35-F	1.57	12.44	20928	0.25	16.25	0.215	13.73	31289	139.4	17.00	4849	84.50	6.18								
3242	60-68-F	2.45	12.27	34643	0.38	24.14	0.34	21.72	46479	134.1	16.35	4665	89.96	3.72								
3245	60-75-F	3.18	12.88	44965	0.39	24.65	0.348	22.27	47460	132.1	16.11	4596	90.32	2.86								
3244	60-86-F	2.70	13.28	38178	0.38	24.54	0.360	23.00	47246	85.1	10.38	2960	93.73	3.37								
3201	80-20-F	1.70	13.00	24924	0.21	13.25	0.153	9.77	19052	192.6	17.61	5003	73.74	5.14								
3202	80-30-F	1.44	11.27	21112	0.30	8.98	0.247	15.79	27279	176.4	16.13	4582	83.20	6.09								
3203	80-40-F	1.40	11.37	20525	0.36	22.82	0.300	19.17	32806	201.9	18.46	5245	84.01	6.29								
3204	80-40-F	1.49	10.88	21845	0.35	22.63	0.305	19.51	32533	172.5	15.78	4481	86.23	5.88								
3238	80-55-F	2.27	11.28	30259	0.42	26.54	0.367	23.44	38328	171.7	15.70	4460	88.31	4.24								
3239	80-58-F	2.15	11.09	28660	0.44	28.20	0.400	25.55	40721	146.5	13.40	3822	90.61	4.49								
3241	80-65-F	1.81	11.82	24127	0.47	29.80	0.406	25.97	43034	212.0	19.39	5531	87.15	5.33								
3208	100-25-F	1.37	11.52	20086	0.32	20.45	0.254	16.23	23522	233.5	17.08	4852	79.37	6.38								
3211	100-25-F	1.66	11.65	24337	0.32	20.57	0.253	16.20	23763	242.0	17.71	5051	78.74	5.31								
3212	100-25-F	1.32	10.62	19353	0.32	20.40	0.266	16.99	23565	188.6	13.80	3937	83.29	6.68								
3213	100-40-F	1.65	10.87	24191	0.42	26.71	0.351	22.42	30858	237.5	17.38	4957	83.94	5.32								
3214	100-40-F	1.67	10.52	23118	0.41	25.89	0.353	22.57	29905	183.6	13.43	3832	87.19	5.57								
3215	100-45-F	1.79	10.52	24779	0.44	27.96	0.386	24.67	32301	182.2	13.33	3803	88.23	5.22								
3236	100-50-F	1.64	10.25	21861	0.47	29.94	0.429	27.41	34587	140.4	10.27	2931	91.53	5.91								
3237	100-55-F	1.86	10.24	24794	0.49	31.25	0.449	28.69	36102	141.8	10.37	2949	91.80	5.19								
3223	120-20-F	1.41	11.59	19519	0.27	17.30	0.218	13.93	16654	186.7	11.38	3247	80.50	6.61								
3221	120-30-F	1.52	10.04	21041	0.39	25.19	0.323	20.64	24251	252.1	15.37	4385	81.91	6.13								
3230	120-40-F	1.68	10.28	22394	0.46	29.49	0.402	25.72	28266	209.1	12.75	3621	87.19	5.75								
3216	120-50-F	1.97	10.69	27271	0.47	30.31	0.421	26.88	29136	190.1	11.59	3307	88.67	4.74								
3217	120-50-F	2.03	10.58	28101	0.50	32.22	0.444	28.36	31014	213.14	13.01	3712	88.03	4.61								
3225	140-25-F	1.54	11.16	20528	0.38	24.24	0.303	19.34	20002	271.5	14.19	4048	79.76	6.30								
3218	140-35-F	1.91	10.57	26440	0.45	28.71	0.383	24.51	23687	232.6	12.16	3468	85.36	4.89								
3220	140-40-F	1.75	10.37	24225	0.51	32.28	0.434	27.74	26633	250.9	13.11	3741	85.95	5.33								
3229	160-30-F	1.63	10.84	21728	0.46	29.10	0.362	23.13	20916	330.2	15.10	4289	79.50	5.91								
3222	160-35-F	1.82	10.65	25194	0.49	31.41	0.403	25.76	22674	312.6	14.29	4078	82.01	5.14								
3235	160-40-F	1.85	10.69	24661	0.52	33.07	0.434	27.72	23872	295.9	13.53	3860	83.83	5.25								
3228	170-20-F	1.86	12.70	24794	0.32	20.74	0.225	14.37	14091	352.2	16.16	4324	69.31	5.20								
3224	170-35-F	1.69	10.61	22528	0.51	32.77	0.413	26.36	22265	354.4	16.25	4351	80.46	5.72								

(M. P. Special.) (Sheet No. 1)

PENNSYLVANIA RAILROAD COMPANY.

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY.
NORTHERN CENTRAL RAILWAY COMPANY.
WEST JERSEY & SEASHORE RAILROAD COMPANY.

TEST DEPARTMENT.

LOCOMOTIVE TESTING PLANT.

TEST OF LOCOMOTIVE No. 1134 TYPE 2-8-0 CLASS H8b BUILT AT Juniata Shops, Altoona, Penna., 1909

Consolidation Type locomotive, Saturated Steam PRESENTED FOR TEST BY Pennsylvania Railroad Company

TESTED AT Altoona Locomotive Test Plant TESTED September 1928 TEST Nos. 2770 TO 2779 SERIES No. 2700

No.	DESCRIPTION, DIMENSIONS AND PROPORTIONS.	
	DRIVING WHEELS.	
1	Number of pairs	4
2	Approximate diameter, inches	62
	MEASURED CIRCUMFERENCE, FEET.	
3	Right, No. 1	16.13
4	" " 2	16.13
5	" " 3	16.13
6	" " 4	16.13
7	" " 5	
8	Left, " 1	16.13
9	" " 2	16.13
10	" " 3	16.13
11	" " 4	16.13
12	" " 5	
13	Average	16.13
	ENGINE TRUCK WHEELS.	
14	Number	2
15	Diameter, inches	31.68
	TRAILING WHEELS.	
16	Diameter, inches	0
	WHEEL BASE, FEET.	
17	Driving wheel base	17.04
18	Total wheel base	25.83
19	Gauge of wheels, in inches	56.5
	DESCRIPTIONS, DIMENSIONS AND PROPORTIONS.	
	VALVES.	
82	Type	Piston
83	Design	
84	Per cent. of balanced to total area	100
85	Type of link motion	Walschaerts
	GREATEST VALVE TRAVEL, INCHES.	
86	High pressure, right	
87	" " left	
88	Low " right	-
89	" " left	-
	STEAM LAP OF VALVE, INCHES.	
90	High Pressure, right, head end	0.87
91	" " " crank "	0.87
92	" " left, head "	0.87
93	" " " crank "	0.87
94	Low " right, head "	-
95	" " " crank "	-
96	" " left, head "	-
97	" " " crank "	-
	EXHAUST LAP OF VALVE, INCHES.	
98	High Pressure, right, head end	0.16
99	" " " crank "	0.16
100	" " left, head "	0.16
101	" " " crank "	0.16
102	Low " right, head "	-
103	" " " crank "	-
104	" " left, head "	-
105	" " " crank "	-
	MISCELLANEOUS.	
106	Cylinder lagging material	Magnesia
107	" jacket "	Sheet Iron
108		
109		

No.	WEIGHT OF ENGINE WITH WATER AT 2ND GAUGE COCK AND NORMAL FIRE, IN POUNDS.	
20	On truck	27300
21	" 1st drivers	58100
22	" 2nd "	49000
23	" 3rd "	54200
24	" 4th "	49700
25	" 5th "	-
26	" trailers	-
27	Total	238300
28	" on drivers	211000
	CYLINDERS.	
29	High pressure, number	2
30	Low "	
31	Arrangement	Outside
	DIAMETER, INCHES.	
32	High pressure, right	24.047
33	" " left	24.048
34	Low " right	-
35	" " left	-
	STROKE OF PISTON, FEET.	
36	High pressure, right	2.334
37	" " left	2.332
38	Low " right	-
39	" " left	-
110		
111		
112		
	BOILER.	
113	Type	Belpaire, Wide Firebox
114	Outside diameter, 1st ring, inches	78.5
	TUBES.	
115	Number	465
116	Outside diameter, inches	2
117	Thickness, inches	0.125
118	Length between tube sheets, inches	181.08
119	Total fire area, square feet	7.77
120	Serve Tubes, number of ribs	-
121	" " sq. in. of inside surface in one in. of length	-
122		
123		
124	Boiler pressure, lbs. per sq. in.	205
	SUPERHEATER	
125	Number of tubes	-
126	Outside diameter, inches	-
127	Thickness, inches	-
128	Length of tubes, inches	-
129		
130		
131		
	FIRE BOX (SIZE INSIDE, INCHES.)	
132	Length	114.6
133	Width	68.375
134	Depth, front end	67.75
135	" back "	58.75
136	Volume, cubic feet	202.26
137	Air inlets to ashpan, sq. ft.	7.2
138		
139		
140		

No.	CLEARANCE PER CENT. OF PISTON DISPLACEMENT.	
40	H. P., right, head end	
41	" " crank "	
42	" left, head "	
43	" " crank "	
44	L. P. right, head "	-
45	" " crank "	-
46	" left, head "	-
47	" " crank "	-
	RECEIVER, CUBIC FEET.	
48	Volume, right side	-
49	" left "	-
	STEAM PORTS, INCHES. (For piston valves the length equals the circumference of inside of bushing minus the sum of the widths of bridges.)	
50	H. P. admission, right, head end, length	36.53
51	" " " " " width	2.01
52	" " " crank " length	36.65
53	" " " " " width	2.01
54	" " left, head " length	36.64
55	" " " " " width	2.00
56	" " " crank " length	36.68
57	" " " " " width	2.00
58	L. P. " right, head " length	-
59	" " " " " width	-
	FIRE DOORS.	
141	Number	One
142	Area square feet	1.60
143		
	GRATES.	
144	Style	Rocking Finger
145	Total area, square feet	53.90
146	" " dead grates, square feet	5.0
147	Width of air spaces, inches	1.5
	AIR INLET AREAS, SQUARE FEET.	
148	Through firebox sides	0.016
149	" grates	15.67
150	" fire doors	0.05
151	Total air inlets, (148), (149) and (150)	15.736
152	Ratio " " (149) to grate area (145)	0.29
153	" " " (151) to " " (145)	0.29
	HEATING SURFACE, SQUARE FEET.	
154	Of the tubes, water side	3673.91
155	" " " fire "	3214.89
156	" " firebox, fire side including arch pipe	188.34
157	" " superheater, fire side	-
158	Total, based on inside of firebox and inside of tubes	3403.23
159	" " " " " " outside of tubes	3862.25
	BOILER VOLUMES With water surface at level of second gauge cock.	
160	Water space, cubic feet	
161	Steam " "	
	EXHAUST NOZZLE.	
162	Double or single	Single
163	Size of right, inches	
164	" " left, "	Rectangular 4½ x 6½ in and Dumbell
165	Area of right, square inches	
166	" " left, " "	
167	Total area, square inches	Rect. 30.80 Dumbell 31.24

No.		
60	L. P. admission, right, crank end, length	-
61	" " " " " width	-
62	" " left, head " length	-
63	" " " " " width	-
64	" " " crank " length	-
65	" " " " " width	-
66	H. P. exhaust, right, length	
67	" " " width	
68	" " left, length	
69	" " " width	
70	L. P. " right, length	-
71	" " " width	-
72	" " left, length	-
73	" " " width	-
	PISTON RODS, DIAMETER, INCHES.	
74	High pressure, right	3.928
75	" " left	3.966
76	Low " right	-
77	" " left	-
	TAIL RODS, DIAMETER, INCHES.	
78	High pressure, right	-
79	" " left	-
80	Low " right	-
81	" " left	-
	REVERSE LEVER.	
168	H. P. cylinder, notches forward of centre	21
169	L. P. " " " "	-
170		
	RATIOS.	
171	Heating surface (158) to grate area (145)	63.14
172	Fire area through tubes (119) to grate area (145)	0.14
173	Firebox heating surface (156) to grate area (145)	3.08
174	Tube surface (155) to firebox heating surface (156)	19.34
175	Firebox volume (136) to grate area (145)	3.75
176		
177		
178		
	CONSTANTS	
179	For dynamometer H. P., (power developed when the speed is one R. P. M. and the pull is one pound)	0.0004888
	FOR INDICATED HORSE POWER, (power developed at one R. P. M. and one pound M. E. P.)	
180	High Pressure Cylinder, right, head end	0.03212
181	" " " " crank "	0.03126
182	" " " left, head "	0.03210
183	" " " " crank "	0.03122
184	Low " " right, head "	-
185	" " " " crank "	-
186	" " " left, head "	-
187	" " " " crank "	-
	PISTON DISPLACEMENT, CUBIC FEET.	
188	High pressure Cylinder, right, head end	7.361
189	" " " " crank "	7.164
190	" " " left, head "	7.356
191	" " " " crank "	7.154
192	Low " " right, head "	-
193	" " " " crank "	-
194	" " " left, head "	
195	" " " " crank "	

(M. P. Special.) TEST OF LOCOMOTIVE No. 1134 TYPE 2-8-0 CLASS H8b (Sheet No. 3)

SUMMARY OF AVERAGE RESULTS.

Test Number	Laboratory Designation	Duration of Test, Hours	Speed: Revolutions: Total	Speed: Revolutions: Average Per Minute	Speed: Equivalent: Speed in Miles Per Hour	Speed: Equivalent: Piston Speed in Feet Per Minute	Position of Levers: Reverse, Notches From Front End	Position of Levers: Kind of Nozzle	Position of Levers: Throttle	Position of Levers: Brick Arch		Temperature, Degrees Fahrenheit, of: Smoke Box: By Thermometer	Smoke Box: By Pyrometer	Laboratory: Dry Bulb	Laboratory: Wet Bulb	Steam in Branch Pipe	Feed Water	Fire Box by Pyrometer		Dry Steam per Hour to Engines, Pounds	Fuel Loss due to Steam Loss Pounds per Hour	Steam Lost from Boiler Pounds per Hour
		196	197	198	199	200	201	202	203	204	205	206	207	208	209	210	211	212	213	214	215	216
2770	60-20-F	2.00	7200	60	11.00	279.96	19.5	Rect. Area 30.88	Full	Without Arch			475	65	61		72.6	1493		15221	19.58	174
2775	60-20-F	2.00	7200	60	11.00	279.96	19.5	Dumbbell Area 31.24	"	With Arch			498	72	66		67.8	1658		15387	49.65	447
2771	80-27-F	2.00	9600	80	14.66	373.28	18.5	Rect. Area 30.88	"	Without			523	65	61		65.2	1576		21407	16.07	144
2776	80-27-F	2.00	9600	80	14.66	373.28	18.5	Dumbbell Area 31.24	"	With			559	70	65		64.5	1746		22370	32.58	287
2772	80-35-F	2.00	9600	80	14.66	373.28	17.5	Rect. Area 30.88	"	Without			564	71	66		62.5	1550		23711	32.35	231
2777	80-35-F	2.00	9600	80	14.66	373.28	17.5	Dumbbell Area 31.24	"	With			560	65	60		65.3	1769		26848	14.87	117
2773	100-42-F	1.00	6000	100	18.33	466.60	16.5	Rect. Area 30.88	"	Without			651	70	65		65.3	1902		35373	0	0
2778	100-42-F	1.00	6000	100	18.33	466.60	16.5	Dumbbell Area 31.24	"	With			647	66	62		62.0	1860		37142	8.89	60
2774	120-42-F	0.50	3600	120	22.00	559.92	16.5	Rect. Area 30.88	"	Without			617	70	65		62.0	1797		35981	0	0
2779	120-42-F	0.75	5400	120	22.00	559.92	16.5	Dumbbell Area 31.24	"	With			655	66	62		61.0	1896		38254	0	0

(M. P. Special.) TEST OF LOCOMOTIVE No. 1134 TYPE 2-8-0 CLASS H8b (SHEET No. 4)

SUMMARY OF AVERAGE RESULTS.

Test Number	Laboratory Designation	Pressure, Pounds per Square Inch. In Boiler. Average.	Pressure: In Boiler. Maximum.	Pressure: In Boiler. Minimum.	Pressure: In Branch Pipe.	Pressure: Air in Laboratory, Barometric.	Draft, Inches of Water. In Smoke Box. Front of Diaphragm.	Draft: In Smoke Box. Back of Diaphragm.	Draft: In Fire Box.	Draft: In Ash Pan.	Injectors. Hours in Action. Total, Right.	Injectors: Hours in Action. Total, Left.	Quality of Steam. In Dome.	Quality of Steam: In Branch Pipe.	Quality of Steam: Degrees of Superheat in Branch Pipe.	Factor of Correction	Coal, Sparks and Ash, Pounds. Coal Fired. Kind.	Coal Fired: Total.	Coal Fired: Per Cent. of Moisture.	Total: Dry Coal Fired.	Total: Combustible by Analysis.	Total: Ash by Analysis.
		217	218	219	220	321	222	223	224	225	226	227	228	229	230	231	232	233	234	235	236	237
2770	60-20-F	203.3	205	200		14.15	2.2	1.1	0.3	0.06	2.0	0				0.9975	Bituminous	3501	2.07	3429	3056	451
2775	60-20-F	204.2	206	203		14.18	2.6	1.4	0.3	0.05	2.0	0				0.9975	"	3607	2.07	3532	3127	444
2771	80-27-F	204.1	205	202		14.16	4.0	2.0	0.5	0.10	2.0	0				0.9973	"	4909	2.07	4807	4256	604
2776	80-27-F	204.9	206	203		14.18	4.6	2.3	0.7	0.11	2.0	0				0.9973	"	5185	2.07	5076	4494	638
2772	80-35-F	202.5	205	198		14.10	6.1	3.0	1.0	0.14	2.0	0				0.9984	"	7702	2.07	7543	6678	947
2777	80-35-F	203.1	205	198		14.17	6.6	3.6	1.0	0.15	2.0	0				0.9984	"	7000	2.07	6855	6069	861
2773	100-42-F	194.6	201	187		14.15	9.4	4.3	1.3	0.21	1.0	0				0.9983	"	5799	2.07	5679	5028	713
2778	100-42-F	203.3	205	202		14.13	11.0	5.6	1.2	0.25	1.0	0				0.9983	"	5628	2.07	5512	4879	692
2774	120-42-F	182.8	187	178		14.15	10.0	5.1	2.0	0.20	0.5	0				0.9983	"	3193	2.07	3127	2768	393
2779	120-42-F	192.2	202	174		14.13	11.7	6.4	2.1	0.23	0.75	0				0.9983	"	5000	2.07	4897	4335	615

(M. P. Special.) TEST OF LOCOMOTIVE No. 1134 TYPE 2-8-0 CLASS H8b (Sheet No. 5)

SUMMARY OF AVERAGE RESULTS.

Test Number	Laboratory Designation	Coal, Sparks and Ash, Lbs. Total: Cinders Collected in Smoke Box	Sparks Discharged From Stack	Dry Sparks Percent of dry Coal Fired	Analysis of Coal, Per Cent.: Fixed Carbon	Volatile Matter	Moisture	Ash	Sulphur, Determined Separately			Calorific Value per Lb. of Fuel, B. T. U.: Of Dry Coal	Of Combustible	Of Cinders and Sparks			Analysis of Smoke Box Gases, Per Cent.: Oxygen O	Carbon Monoxide CO	Carbon Dioxide CO_2	Nitrogen N		Smoke Ringelmann Scale
		238	239	240	241	242	243	244	245	246	247	248	249	250	251	252	253	254	255	256	257	258
2770	60-20-F			-	54.40	32.30	1.00	12.30	2.49			13369	15265				8.0	-	11.0	81.0		20
2775	60-20-F			2.47	54.40	32.30	1.00	12.30	2.49			13369	15265				4.0	-	14.4	81.6		8
2771	80-27-F			-	54.40	32.30	1.00	12.30	2.49			13369	15265				9.6	-	9.6	81.8		22
2776	80-27-F			4.72	54.40	32.30	1.00	12.30	2.49			13369	15265				9.3	-	8.4	82.3		10
2772	80-35-F			9.18	54.40	32.30	1.00	12.30	2.49			13369	15265				8.6	0.6	8.2	82.6		32
2777	80-55-F			6.90	54.40	32.30	1.00	12.30	2.49			13369	15265				8.8	-	9.6	81.6		12
2773	100-42-F			11.30	54.40	32.30	1.00	12.30	2.49			13369	15265					Sample Lost				38
2778	100-42-F			17.95	54.40	32.30	1.00	12.30	2.49			13369	15265				6.6	-	11.2	82.2		24
2774	120-42-F			11.30	54.40	32.30	1.00	12.30	2.49			13369	15265				4.4	0.8	12.6	82.2		42
2779	120-42-F			17.93	54.40	32.30	1.00	12.30	2.49			13369	15265				5.4	0.2	9.8	84.6		36

(M. P. Special.) TEST OF LOCOMOTIVE No. 1134 TYPE 2-8-0 CLASS H8b (Sheet No. 6)

SUMMARY OF AVERAGE RESULTS.

Test Number	Laboratory Designation	WATER, IN POUNDS: Delivered to Injectors	WATER, IN POUNDS: Lost: From Boiler	WATER, IN POUNDS: Lost: From	WATER, IN POUNDS: Lost: From	WATER, IN POUNDS: Lost: Total	WATER, IN POUNDS: Delivered to Boiler and Presumably Evaporated	DYNAMOMETER: Pull in Pounds: Average	DYNAMOMETER: Pull in Pounds: Maximum	DYNAMOMETER: Pull in Pounds: Minimum
		259	260	261	262	263	264	265	266	267
2770	60-20-F	30866					30866	14074	14671	13374
2775	60-20-F	31746					31746	14725	15220	13570
2771	80-27-F	43218					43218	17654	18146	17006
2776	80-27-F	44859					44859	18284	18543	17650
2772	80-35-F	53970					53970	22461	22920	21822
2777	80-35-F	54015					54015	22597	23070	21822
2773	100-42-F	35433					35433	23554	24370	22519
2778	100-42-F	37265					37265	24620	25022	24170
2774	120-42-F	18021					18021	20242	20677	19732
2779	120-42-F	28739					28739	21408	22569	19534

EVENTS OF STROKE FROM INDICATOR CARDS

Test Number	Cut-off, per cent of stroke: High Pressure Cylinder: Right Side: Head End	Right Side: Crank End	Left Side: Head End	Left Side: Crank End	Cut-off: Low Pressure Cylinder: Right Side: Head End	Right Side: Crank End	Left Side: Head End	Left Side: Crank End	Release, per cent of stroke: High Pressure Cylinder: Right Side: Head End	Right Side: Crank End	Left Side: Head End	Left Side: Crank End
	268	269	270	271	272	273	274	275	276	277	278	279
2770	15.4	16.5	21.4	22.7					53.7	52.1	55.6	53.6
2775	18.9	17.5	21.2	24.5					53.8	50.5	60.1	54.4
2771	24.7	25.8	28.3	31.1					59.0	57.2	61.1	58.8
2776	26.3	28.6	28.3	33.7					61.1	57.6	66.0	58.9
2772	33.7	33.6	34.8	40.0					66.4	64.0	67.3	65.7
2777	33.9	33.8	33.9	41.9					65.4	64.3	69.8	65.9
2773	43.6	43.9	41.7	51.9					70.4	68.5	74.4	70.9
2778	40.1	41.7	44.1	51.0					70.5	68.1	73.9	70.1
2774	41.5	37.3	37.5	44.8					72.4	69.4	72.1	73.6
2779	42.3	35.7	37.3	42.0					72.3	66.6	73.7	71.1

(M. P. Special.) TEST OF LOCOMOTIVE No. 1134 TYPE 2-8-0 CLASS H8b (Sheet No. 7)

SUMMARY OF AVERAGE RESULTS.

Test	Laboratory	EVENTS OF STROKE FROM INDICATOR CARDS												PRESSURE FROM INDICATOR CARDS								Factor
		RELEASE, PER CENT. OF STROKE				BEGINNING OF COMPRESSION, PER CENT. OF STROKE								INITIAL PRESSURES, POUNDS PER SQUARE INCH								of
		LOW PRESSURE CYLINDER				HIGH PRESSURE CYLINDER				LOW PRESSURE CYLINDER				HIGH PRESSURE CYLINDER				LOW PRESSURE CYLINDER				Evapora
Number	Designation	RIGHT SIDE		LEFT SIDE		RIGHT SIDE		LEFT SIDE		RIGHT SIDE		LEFT SIDE		RIGHT SIDE		LEFT SIDE		RIGHT SIDE		LEFT SIDE		-tion
		Head End	Crank End	Head End	Crank End	Head End	Crank End	Head End	Crank End	Head End	Crank End	Head End	Crank End	Head End	Crank End	Head End	Crank End	Head End	Crank End	Head End	Crank End	
		280	281	282	283	284	285	286	287	288	289	290	291	292	293	294	295	296	297	298	299	300
2770	60-20-F													192.8	198.7	193.8	188.5					1.1941
2775	60-20-F													200.3	195.7	200.7	170.4					1.1991
2771	80-27-F													188.5	190.2	188.2	190.4					1.2017
2776	80-27-F													193.2	186.9	190.5	170.4					1.2025
2772	80-35-F													194.5	188.5	189.8	188.1					1.2044
2777	80-35-F													193.0	196.2	187.3	181.8					1.2037
2773	100-42-F													187.0	189.9	183.1	168.0					1.2029
2778	100-42-F													198.4	201.2	190.6	173.1					1.2050
2774	120-42-F													170.0	172.0	171.3	158.8					1.2034
2779	120-42-F													177.8	178.0	177.3	165.2					1.2051

(M. P. Special.) TEST OF LOCOMOTIVE No. 1134 TYPE 2-8-0 CLASS H8b (Sheet No. 8)

SUMMARY OF AVERAGE RESULTS.

PRESSURES FROM INDICATOR CARDS

Test Number	Laboratory Designation	Steam Chest Pressures, Pounds per Square Inch: High Pressure, Right Side	Steam Chest: High Pressure, Left Side	Steam Chest: Low Pressure, Right Side	Steam Chest: Low Pressure, Left Side		Cut-off, H.P. Cylinder, Right Side, Head End	Cut-off, H.P. Cylinder, Right Side, Crank End	Cut-off, H.P. Cylinder, Left Side, Head End	Cut-off, H.P. Cylinder, Left Side, Crank End	Cut-off, L.P. Cylinder, Right Side, Head End	Cut-off, L.P. Cylinder, Right Side, Crank End	Cut-off, L.P. Cylinder, Left Side, Head End	Cut-off, L.P. Cylinder, Left Side, Crank End	Release, H.P. Cylinder, Right Side, Head End	Release, H.P. Cylinder, Right Side, Crank End	Release, H.P. Cylinder, Left Side, Head End	Release, H.P. Cylinder, Left Side, Crank End	Release, L.P. Cylinder, Right Side, Head End	Release, L.P. Cylinder, Right Side, Crank End	Release, L.P. Cylinder, Left Side, Head End	Release, L.P. Cylinder, Left Side, Crank End
		301	302	303	304	305	306	307	308	309	310	311	312	313	314	315	316	317	318	319	320	321
2770	60-20-F		201.7				159.5	156.9	152.8	137.2					59.8	59.8	61.4	64.9				
2775	60-20-F		206.0				148.4	155.4	160.5	134.4					61.2	64.5	63.2	65.8				
2771	80-27-F		200.5				139.0	141.8	140.3	132.5					64.4	67.5	65.4	74.4				
2776	80-27-F		207.4				139.3	138.5	143.2	129.1					65.7	70.5	65.0	76.2				
2772	80-55-F		203.3				140.2	151.8	144.4	145.5					74.4	81.8	74.0	90.2				
2777	80-35-F		201.8				143.0	151.4	154.3	146.4					76.2	81.8	75.9	96.4				
2773	100-42-F		197.3				130.4	135.4	138.3	135.7					82.3	86.4	77.7	101.0				
2778	100-42-F		205.3				144.3	143.0	144.0	146.0					85.6	89.5	87.7	107.0				
2774	120-42-F		183.0				120.3	127.8	128.5	123.8					68.8	71.5	67.0	74.8				
2779	120-42-F		193.7				126.8	142.4	139.0	131.3					73.0	76.4	71.0	79.8				

(M. P. Special.) TEST OF LOCOMOTIVE No. 1134 TYPE 2-8-0 CLASS H8b (Sheet No 9.)

Test Number	Laboratory Designation	SUMMARY OF AVERAGE RESULTS. PRESSURES FROM INDICATOR CARDS. PRESSURES AT BEGINNING OF COMPRESSION, POUNDS PER SQUARE INCH								LEAST BACK PRESSURE, POUNDS PER SQUARE INCH								SUMMARY OF AVERAGE RESULTS, BOILER. DRY COAL FIRED		EVAPORATION, POUNDS			
		HIGH PRESSURE CYLINDER				LOW PRESSURE CYLINDER				HIGH PRESSURE CYLINDER				LOW PRESSURE CYLINDER				Per Hour	Per Square Foot of Grate Surface	STEAM PER HOUR			Dry Steam Per Pound of Dry Coal Fired
		RIGHT SIDE		LEFT SIDE		RIGHT SIDE		LEFT SIDE		RIGHT SIDE		LEFT SIDE		RIGHT SIDE		LEFT SIDE				Moist	Dry	Dry, Per Sq. Ft. of Heating Surface	
		Head End	Crank End	Head End	Crank End	Head End	Crank End	Head End	Crank End	Head End	Crank End	Head End	Crank End	Head End	Crank End	Head End	Crank End						
		322	323	324	325	326	327	328	328	330	331	332	333	334	335	336	337	338	339	340	341	342	343
2770	60-20-F									0.7	0.8	0.4	0.0					1715	31.82	15433	15394	4.52	8.98
2775	60-20-F									0.8	0.2	0.4	0.9					1766	32.76	15875	15833	4.65	8.97
2771	80-27-F									1.2	1.9	0.4	0.9					2404	44.60	21609	21551	6.33	8.96
2776	80-27-F									1.2	0.4	2.3	0.5					2538	47.09	22430	22369	6.57	8.81
2772	80-35-F									1.3	2.6	0.8	2.8					3772	69.98	26985	26942	7.92	7.14
2777	80-35-F									1.5	4.1	2.0	1.9					3428	63.60	27008	26965	7.92	7.87
2773	100-42-F									6.7	5.9	6.3	7.1					5679	105.36	35433	35373	10.39	6.23
2778	100-42-F									5.6	6.2	8.0	5.6					5512	102.26	37265	37202	10.93	6.75
2774	120-42-F									7.3	7.5	7.5	8.0					6254	116.03	36042	35981	10.57	5.75
2779	120-42-F									5.7	6.8	7.8	7.0					6529	121.13	38319	38254	11.24	5.86

(M. P. Special.) TEST OF LOCOMOTIVE No. 1134 TYPE 2-8-0 CLASS H8b (Sheet No. 10)

SUMMARY OF AVERAGE RESULTS, BOILER.

Test Number	Laboratory Designation	Equiv't Evap'n from and at 212° F., lbs.: Per Hour	Per Hour, Per Square Foot of Heating Surface	Per Pound of: Coal as Fired	Dry Coal as Fired	Combustible	Boiler Horse Power	Efficiency of Boiler
		344	345	346	347	348	349	350
2770	60-20-F	18382	5.40	10.50	10.72	12.11	532.8	77.81
2775	60-20-F	18985	5.58	10.63	10.75	12.14	550.3	78.03
2771	80-27-F	25898	7.61	10.55	10.77	12.17	750.7	78.17
2776	80-27-F	26899	7.90	10.38	10.60	11.97	779.7	76.94
2772	80-55-F	32449	9.55	8.45	8.60	9.72	940.6	62.42
2777	80-55-F	32458	9.54	9.27	9.47	10.70	940.8	66.74
2773	100-42-F	42550	12.50	7.34	7.49	8.46	1233.3	54.37
2778	100-42-F	44828	13.17	7.97	8.15	9.19	1299.4	59.01
2774	120-42-F	43300	12.72	6.78	6.92	7.82	1255.1	50.23
2779	120-42-F	46100	13.56	5.76	7.06	7.98	1336.2	51.25

SUMMARY OF AVERAGE RESULTS, ENGINES.

Test Number	MEP, High Pressure Cylinder, Right Side, Head End	HP Right Side, Crank End	HP Left Side, Head End	HP Left Side, Crank End	MEP, Low Pressure Cylinder, Right Side, Head End	LP Right Side, Crank End	LP Left Side, Head End	LP Left Side, Crank End	Receiver Pressure, Right Side	Receiver Pressure, Left Side	Number of Expansions, Right Side, Head End	Right Side, Crank End	Left Side, Head End	Left Side, Crank End
	351	352	353	354	355	356	357	358	359	360	361	362	363	364
2770	68.71	65.76	73.89	71.31										
2775	68.25	66.33	75.84	71.40										
2771	81.05	80.38	84.70	87.91										
2776	83.34	82.66	84.83	87.29										
2772	98.22	98.26	98.36	107.23										
2777	99.28	100.73	102.23	109.20										
2773	100.90	104.37	104.07	112.01										
2778	106.96	104.76	109.96	116.84										
2774	87.86	87.96	88.67	94.62										
2779	93.69	91.84	94.13	97.46										

(M. P. Special.) TEST OF LOCOMOTIVE No. 1134 TYPE 2-8-0 CLASS H8b (Sheet No. 11)

SUMMARY OF AVERAGE RESULTS, ENGINES.

Test Number	Laboratory Designation	Indicated Horse Power: High Pressure Cylinder, Right Side, Head End	Crank End	Left Side, Head End	Crank End	Low Pressure Cylinder, Right Side, Head End	Crank End	Left Side, Head End	Crank End	Division of Power: High Pressure Cylinder, Right Side	Left Side	Low Pressure Cylinder, Right Side	Left Side	Total, Right Side	Left Side	Total I.H.P.	Consumed per I. H. P., per Hour: Dry Coal, Pounds	Dry Steam, Pounds	B. T. U.	Locomotive: Dynamometer Horse Power	Pounds per D. H. P., per Hour: Of Dry Coal	Of Dry Steam	B. T. U. per D. H. P. per Hour
		365	366	367	368	369	370	371	372	373	374	375	376	377	378	379	380	381	382	383	384	385	386
2770	60-20-F	132.42	123.34	142.31	133.58					255.76	275.89					531.7	3.23	28.65	43182	412.6	4.15	36.87	53481
2775	60-20-F	131.53	124.41	146.07	133.75					255.94	279.82					535.8	3.30	28.72	44118	431.9	4.09	35.63	54679
2771	80-27-F	208.26	201.02	217.51	219.57					409.28	437.08					846.4	2.84	25.29	37958	690.3	3.48	31.01	46524
2776	80-27-F	214.15	206.72	217.84	218.02					420.87	435.86					856.7	2.96	26.11	39572	715.0	3.55	31.29	47460
2772	80-35-F	252.38	245.70	252.59	267.82					498.08	520.41					1018.5	3.70	26.23	49465	879.1	4.29	30.38	57353
2777	80-35-F	255.11	251.90	262.53	272.74					507.01	535.27					1042.3	3.29	25.76	43984	883.6	3.88	30.38	51872
2773	100-42-F	324.09	326.26	234.06	349.70					650.35	683.76					1334.1	4.26	26.51	56952	1150.3	4.94	30.75	66045
2778	100-42-F	243.56	327.48	352.97	364.77					671.04	717.74					1388.8	3.97	26.74	53075	1203.4	4.58	30.86	61230
2774	120-42-F	338.65	329.95	341.56	354.48					668.60	696.04					1364.6	4.58	26.37	61230	1187.3	5.27	30.30	70455
2779	120-42-F	361.12	344.51	362.59	365.09					705.63	727.68					1433.3	4.56	26.69	60963	1255.7	5.20	30.46	69515

(M. P. Special.) TEST OF LOCOMOTIVE No. 1134 TYPE 2-8-0 CLASS E6b (Sheet No 12.)

SUMMARY OF AVERAGE RESULTS, LOCOMOTIVE.

Test Number	Laboratory Designation	LOCOMOTIVE: Per One Million Foot Pounds at Draw-Bar: Dry Coal, Pounds	Dry Steam, Pounds	B. T. U.	I. H. P. per Square Foot of: Heating Surface	Grate Surface	D. H. P. per Square Foot of: Heating Surface	Grate Surface	Tractive Power Based on M. E. P., Pounds	Machine Friction of Locomotive, in Terms of: Horse Power	M. E. P., Pounds	Draw-Bar Pull, Pounds	Machine Efficiency of Locomotive, Per Cent.	Efficiency of Locomotive, Per Cent.	RATIOS: Total Weight of Locomotive to Maximum I. H. P.	Total Heating Surface to Maximum I. H. P.						
		387	388	389	390	391	382	393	394	395	398	397	398	399	400	401	402	403	404	405	406	407
2770	60-20-F	2.10	18.63	28075	0.16	9.86	0.121	7.66	18128	118.9		4054	77.64	4.59								
2775	60-20-F	2.07	18.00	27674	0.16	9.94	0.127	8.01	18268	103.9		3543	80.61	4.65								
2771	80-27-F	1.76	15.66	23529	0.25	15.70	0.203	12.81	21644	156.1		3992	81.56	5.47								
2776	80-27-F	1.79	15.80	23951	0.25	15.89	0.210	13.27	21910	141.7		3624	83.46	5.36								
2772	80-35-F	2.17	15.33	29011	0.30	18.90	0.258	16.31	26047	139.4		3565	86.31	4.44								
2777	80-35-F	1.96	15.34	26203	0.31	19.34	0.260	16.39	26655	158.7		4059	84.77	4.91								
2773	100-42-F	2.49	15.53	33289	0.39	24.75	0.338	21.34	27294	183.8		3760	86.22	3.85								
2778	100-42-F	2.31	15.59	30882	0.41	25.77	0.354	22.33	28413	185.4		3793	86.65	4.16								
2774	120-42-F	2.66	15.30	35562	0.40	25.32	0.349	22.03	23266	177.3		3025	87.01	3.61								
2779	120-42-F	2.63	15.39	35160	0.42	26.59	0.369	23.30	24436	177.6		3028	87.61	3.66								

GRAPHICAL LOGS OF TESTS.

A graphical log is made for each test to show the conditions at each ten-minute interval, and to indicate any irregularity in the weights of coal and water during the run. These diagrams are on file with the Test Plant records. A few representative ones only being shown here.

M. P. Experimental D-1

12 9 1912
8 x 10½

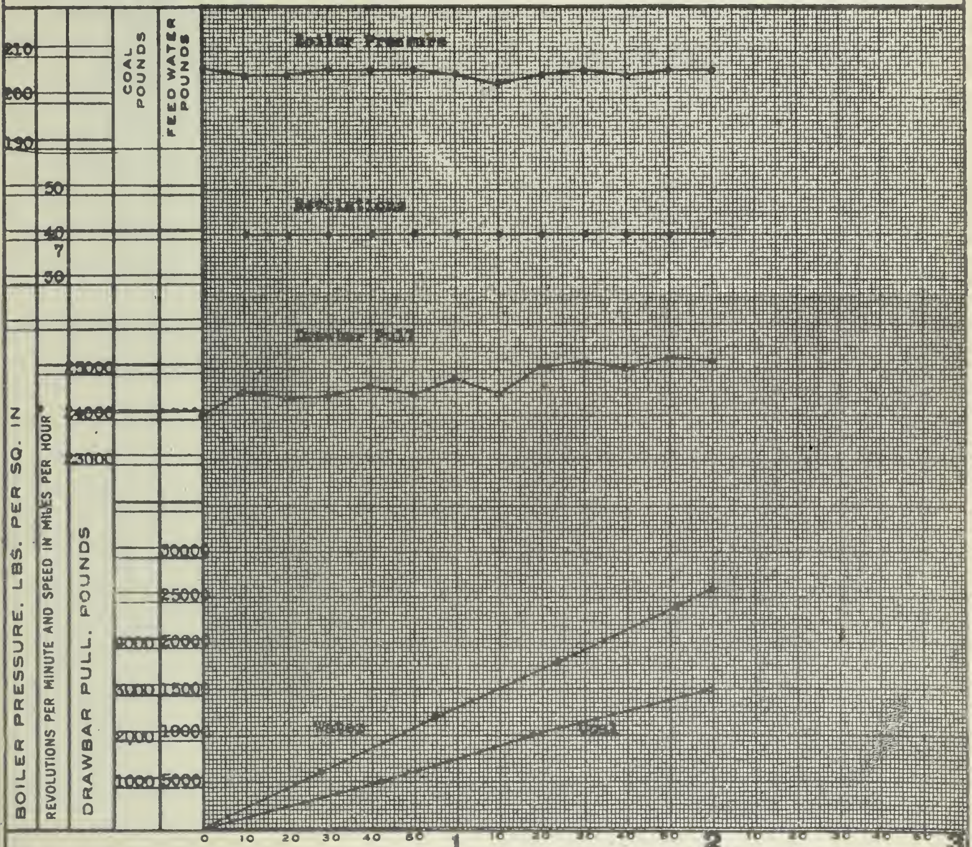
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-1213 TEST DEPARTMENT Bulletin NO. 10

GRAPHICAL LOG OF LOCOMOTIVE TEST

Tests of a Class H8sb Locomotive. ALTOONA, PA. 3-19-1913



LENGTH OF TEST—MINUTES AND HOURS

*UPPER FIGURES R. P. M.
LOWER FIGURES APPROX.
SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 2-8-0
CLASS H8sb
NUMBER 387

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
7.2	40	30	F	8.7

TEST NO. 3210

SHEET NO. P-1213

M. P. Experimental D-1

12 9 1912
8 x 10½

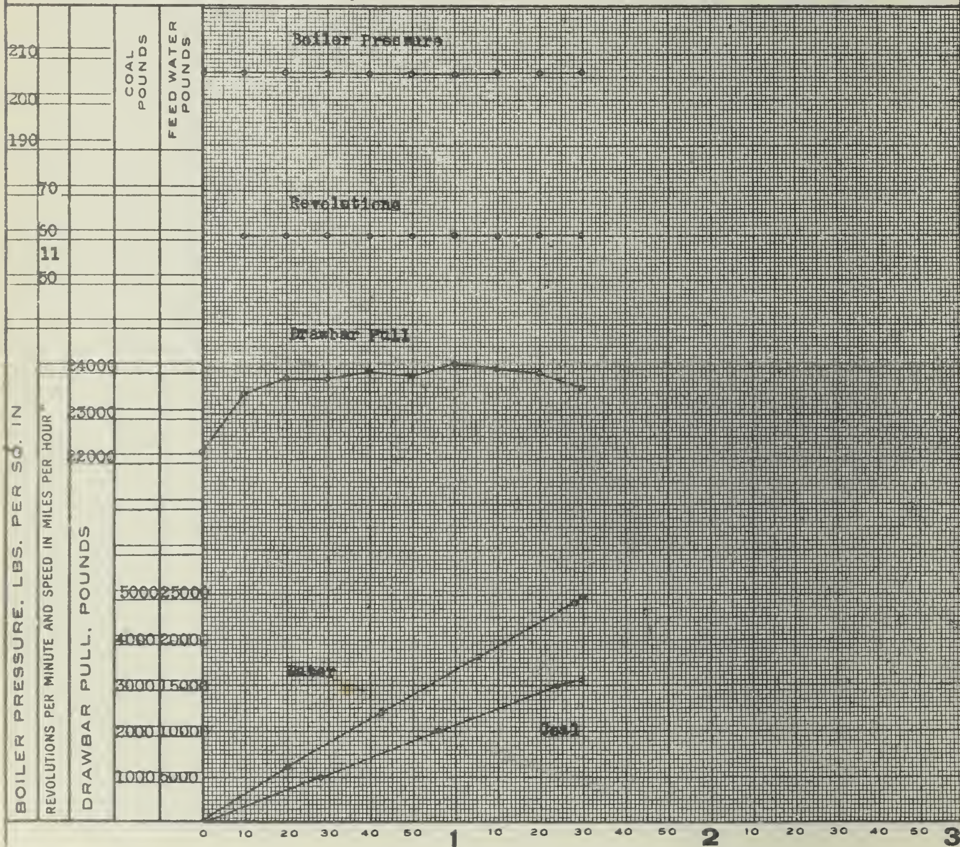
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO P-1214 TEST DEPARTMENT Bulletin NO 10

GRAPHICAL LOG OF LOCOMOTIVE TEST

Tests of a Class H8sb Locomotive. ALTOONA, PA. 3-17-1913



*UPPER FIGURES R. P. M.
LOWER FIGURES APPROX.
SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 2-8-0
CLASS H8sb
NUMBER 387

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
10.8	60	30	F	7.9

TEST NO. 3209

SHEET NO P-1214

M. P. Experimental D-1

12 9 1912
8 x 10½

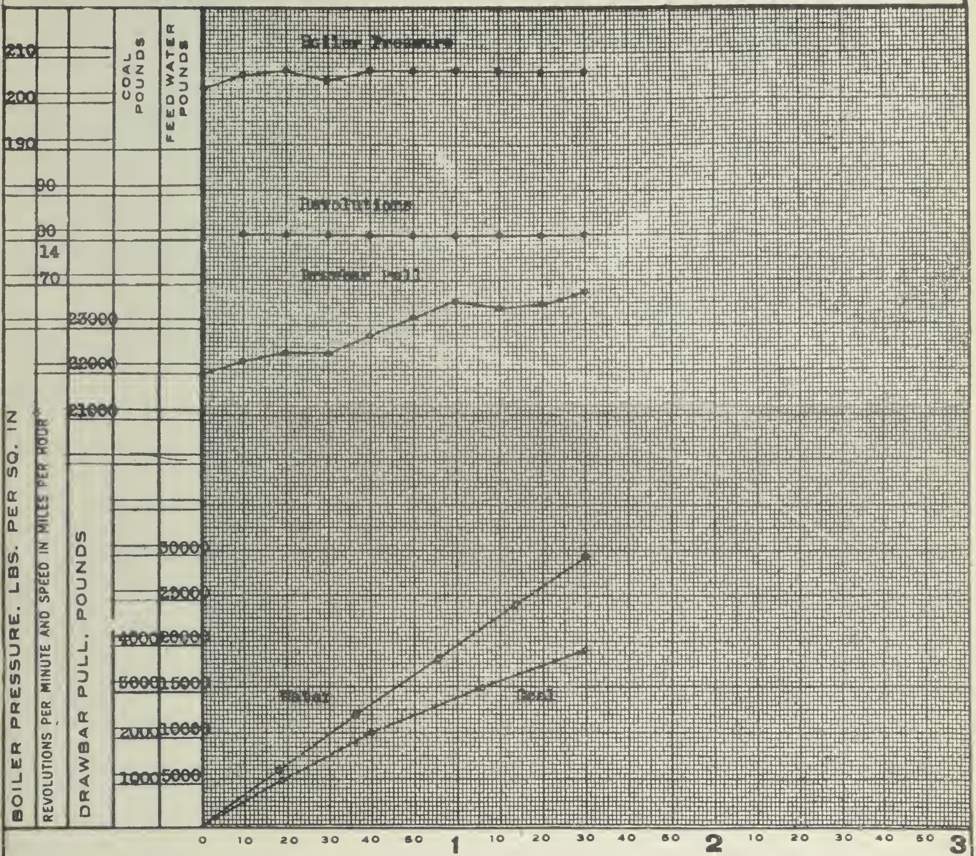
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-1215 TEST DEPARTMENT Bulletin NO. 10

GRAPHICAL LOG OF LOCOMOTIVE TEST

Tests of a Class H8sb Locomotive. ALTOONA, PA. 3-5-1913



LENGTH OF TEST - MINUTES AND HOURS

*UPPER FIGURES R. P. M.
LOWER FIGURES APPROX.
SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 2-8-0
CLASS H8sb
NUMBER 387

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
14.4	80	30	F	7.8

TEST NO. 3202

SHEET NO. P-1215

M. P. Experimental D-1

12 9 1912
8 x 10½

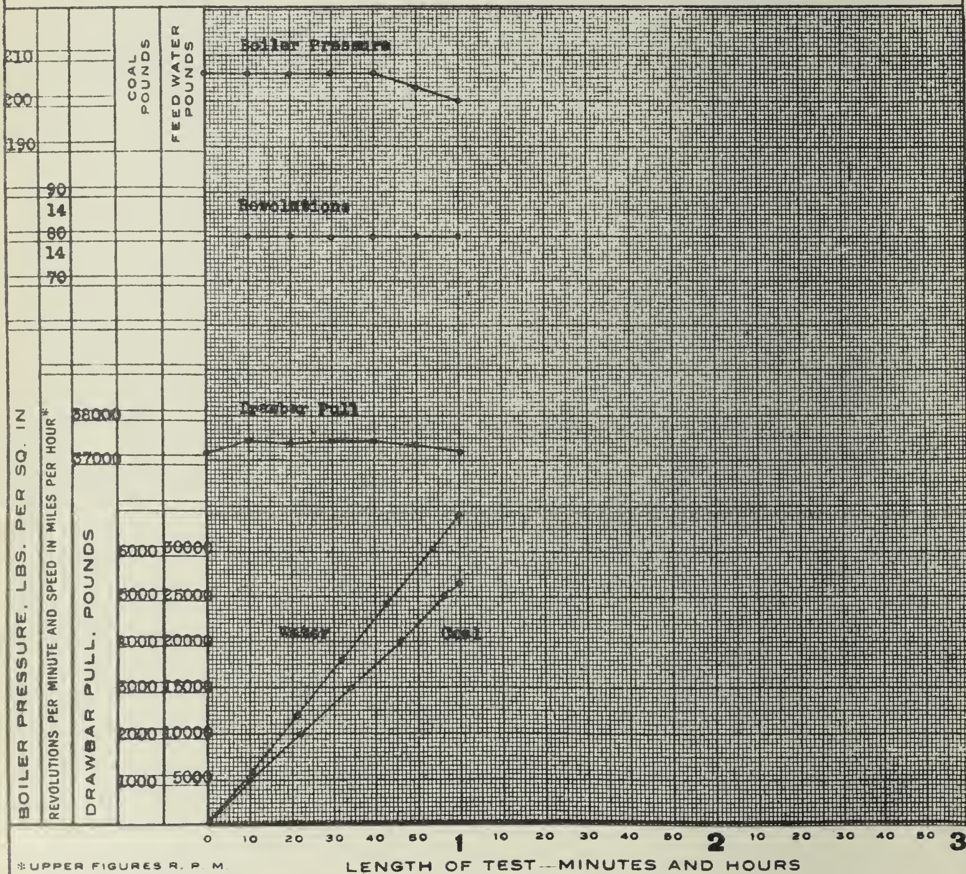
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-1216 TEST DEPARTMENT Bulletin NO. 10

GRAPHICAL LOG OF LOCOMOTIVE TEST

Tests of a Class H8sb Locomotive. ALTOONA, PA. 4-7-1913



*UPPER FIGURES R. P. M.
LOWER FIGURES APPROX. SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 2-8-0
CLASS H8sb
NUMBER 387

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
14.4	80	63	F	6.4

TEST NO. 3241

SHEET NO. P-1216

M. P. Experimental D-1

12 9 1912
8 x 10½

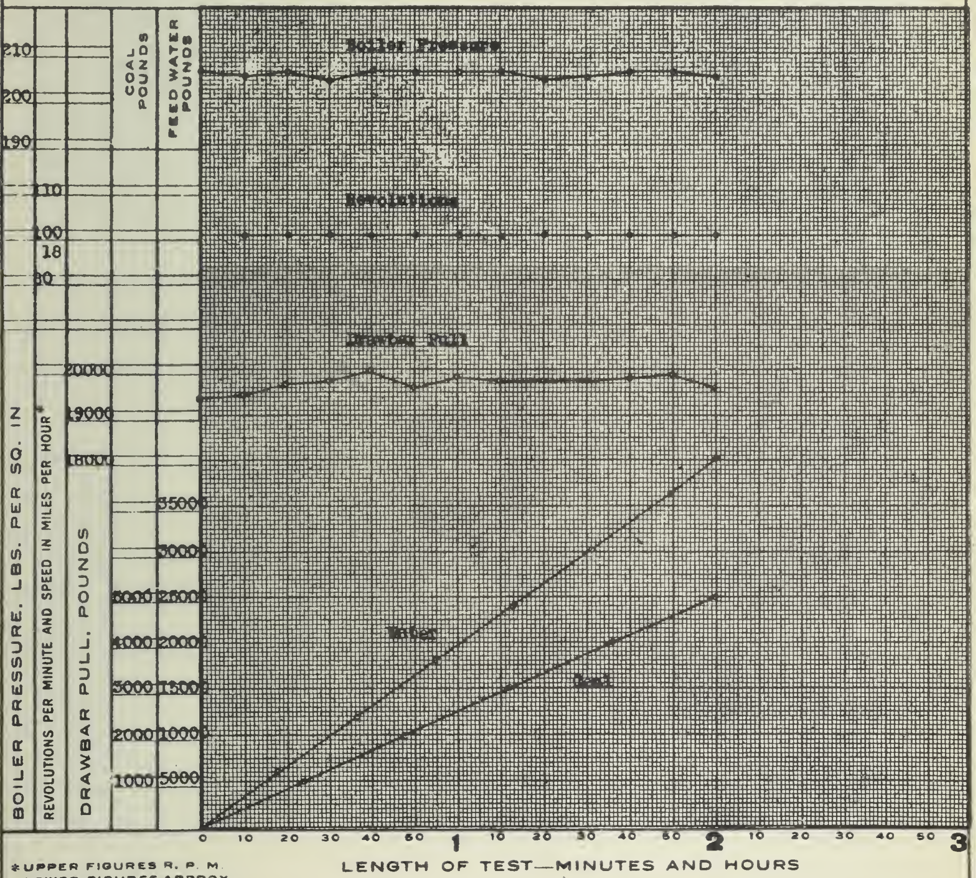
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-1217 TEST DEPARTMENT Bulletin No. 10

GRAPHICAL LOG OF LOCOMOTIVE TEST

Tests of a Class H8sb Locomotive. ALTOONA, PA. 3-20-1913



*UPPER FIGURES R. P. M.
LOWER FIGURES APPROX.
SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 2-8-0
CLASS H8sb
NUMBER 387

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
18.0	100	25	F	8.0

TEST NO. 3212

SHEET NO. P-1217

M. P. Experimental D-1

12 9 1912
6 x 10½

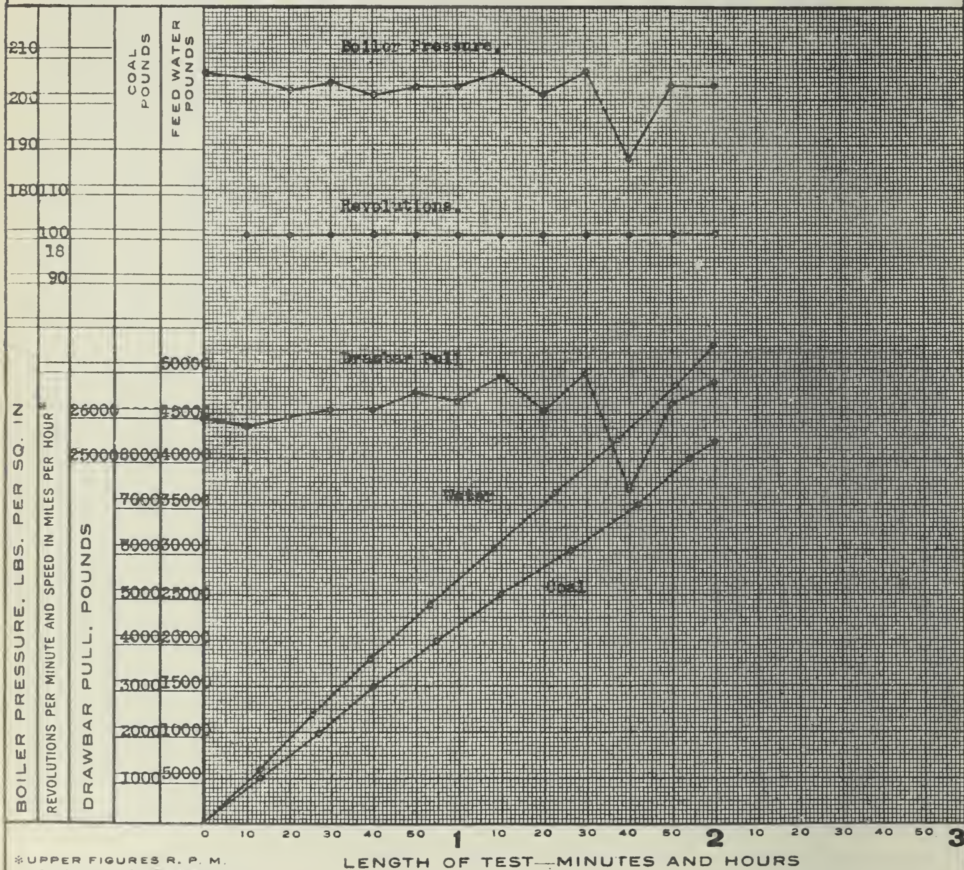
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-1218 TEST DEPARTMENT Bulletin NO. 10

GRAPHICAL LOG OF LOCOMOTIVE TEST

Tests of a Class H8sb Locomotive. ALTOONA, PA. 3-22-1913



*UPPER FIGURES R. P. M.
LOWER FIGURES APPROX.
SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 2-8-0
CLASS H8sb
NUMBER 397

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
18.0	100	40	F	6.3

TEST NO. 3214

SHEET NO. P-1218

M P Experimental D-1

12-9-1912
a 10½

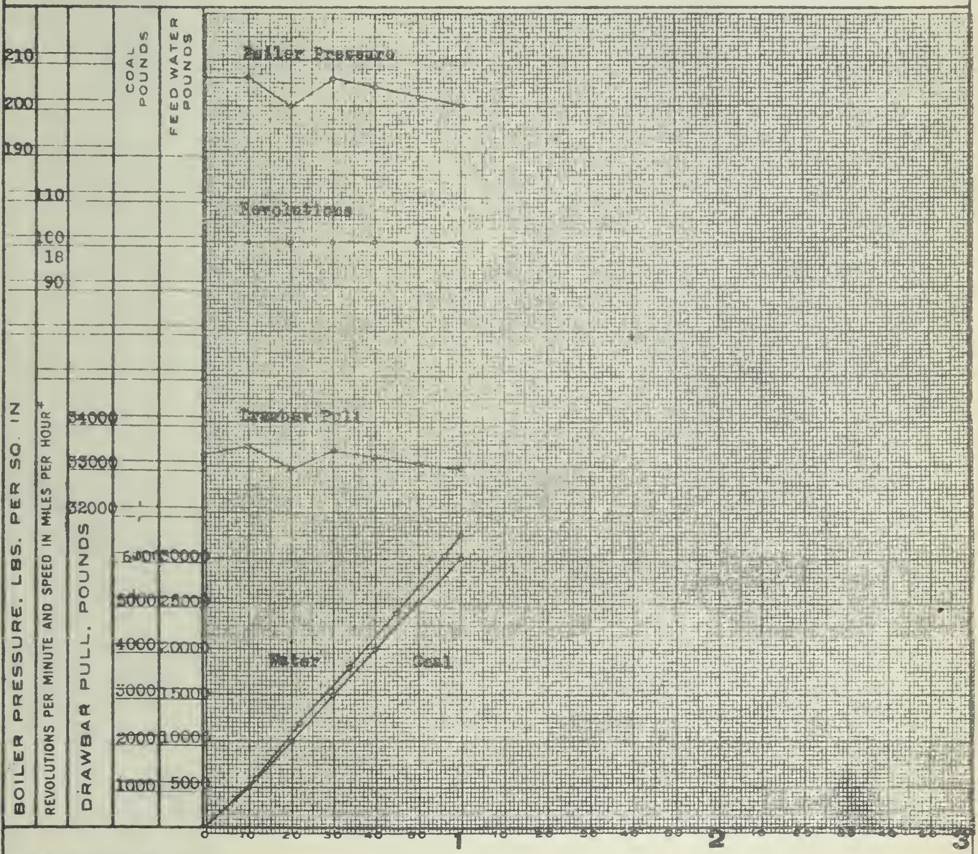
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO P-1219 TEST DEPARTMENT Bulletin NO. 10

GRAPHICAL LOG OF LOCOMOTIVE TEST

Tests of a Class H8sb Locomotive. ALTOONA, PA 4-6-1913



*UPPER FIGURES R. P. M.
LOWER FIGURES APPROX.
SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 2-8-0
CLASS H8sb
NUMBER 367

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
18.0	100	55	F	5.4

TEST NO. 3237

SHEET NO. P-1219

M. P. Experimental D-1

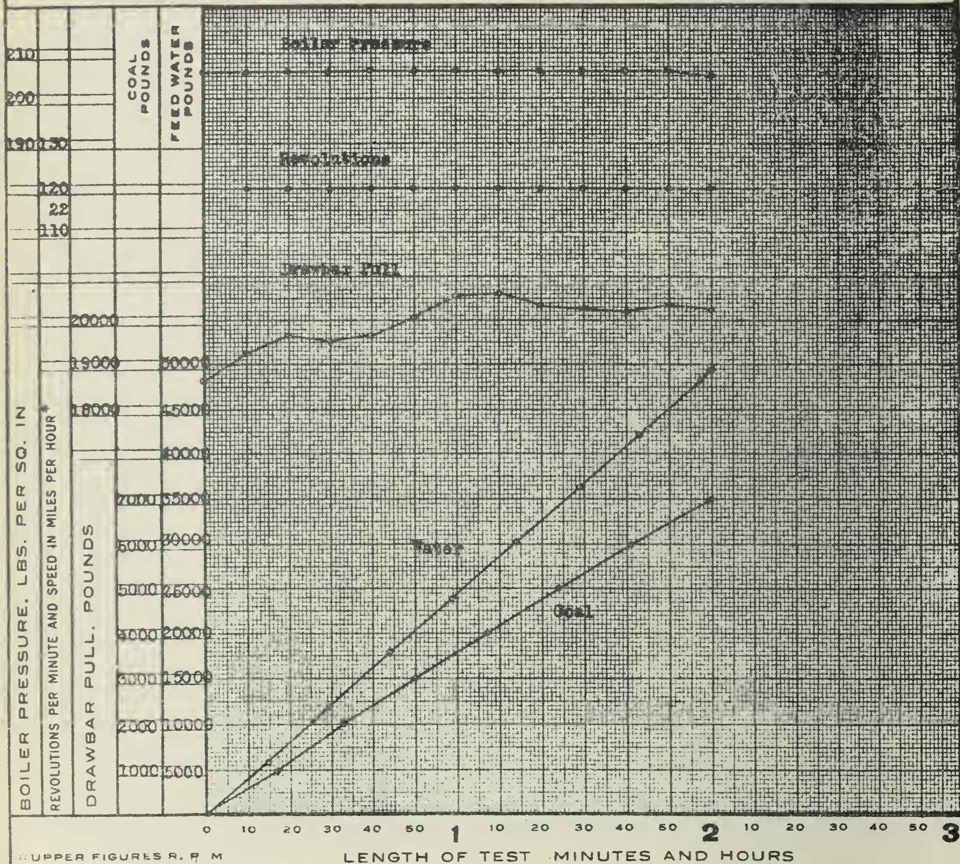
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-1220 TEST DEPARTMENT Bulletin NO. 10

GRAPHICAL LOG OF LOCOMOTIVE TEST

Tests of a Class H8sb Locomotive ALTOONA, PA. 3-26-1913



UPPER FIGURES R. P. M.
LOWER FIGURES APPROX. SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 2-8-0
CLASS H8sb
NUMBER 387

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
21.6	120	30	F	7.1

TEST NO. 3221

SHEET NO. 1220

M. P. Experimental D-1

12 9 '912

8 x 10 3/4

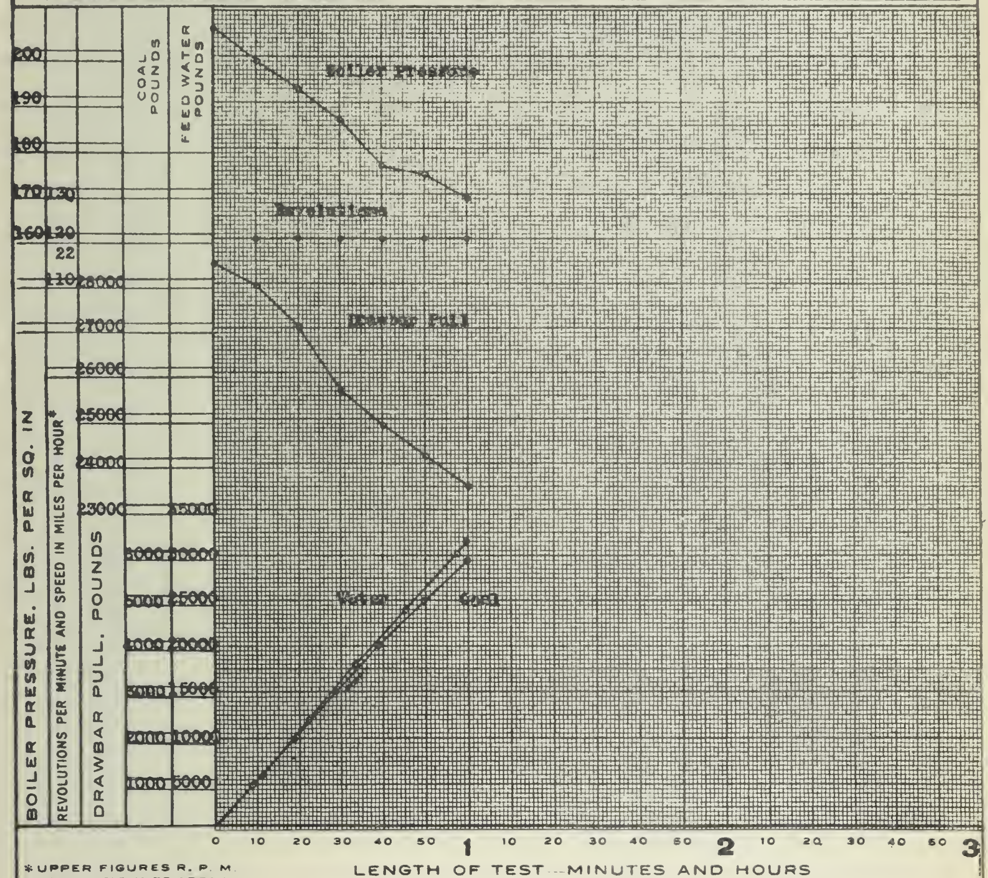
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-1221 | TEST DEPARTMENT | Bulletin NO 10

GRAPHICAL LOG OF LOCOMOTIVE TEST

Tests of a Class H8sb Locomotive. ALTOONA, PA. 3-24-1913



*UPPER FIGURES R. P. M.
LOWER FIGURES APPROX.
SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 2-8-0
CLASS H8sb
NUMBER 387

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
21.6	120	50	F	5.4

TEST NO. 3216

SHEET NO. P-1221

M. P. Experimental D-1

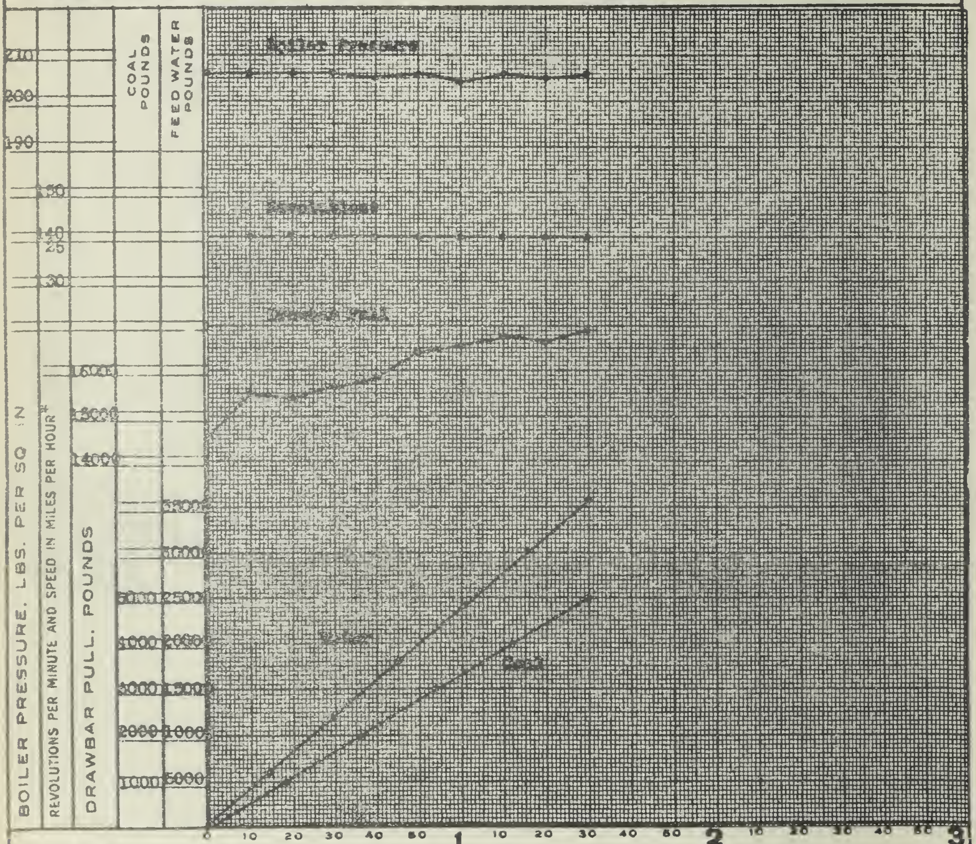
12 9 1912
8 x 10¼

PENNSYLVANIA RAILROAD COMPANY
PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-1222 TEST DEPARTMENT Bulletin NO. 10

GRAPHICAL LOG OF LOCOMOTIVE TEST

Tests of a Class H8sb Locomotive. ALTOONA, PA. 3-28-1913



* UPPER FIGURES R. P. M.
LOWER FIGURES APPROX.
SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 2-8-0
CLASS H8sb
NUMBER 387

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
25.2	140	25	F	7.2

TEST No. 3225

SHEET No. P-1222

M. P. Experimental D-1

12 9 1912
8 x 10½

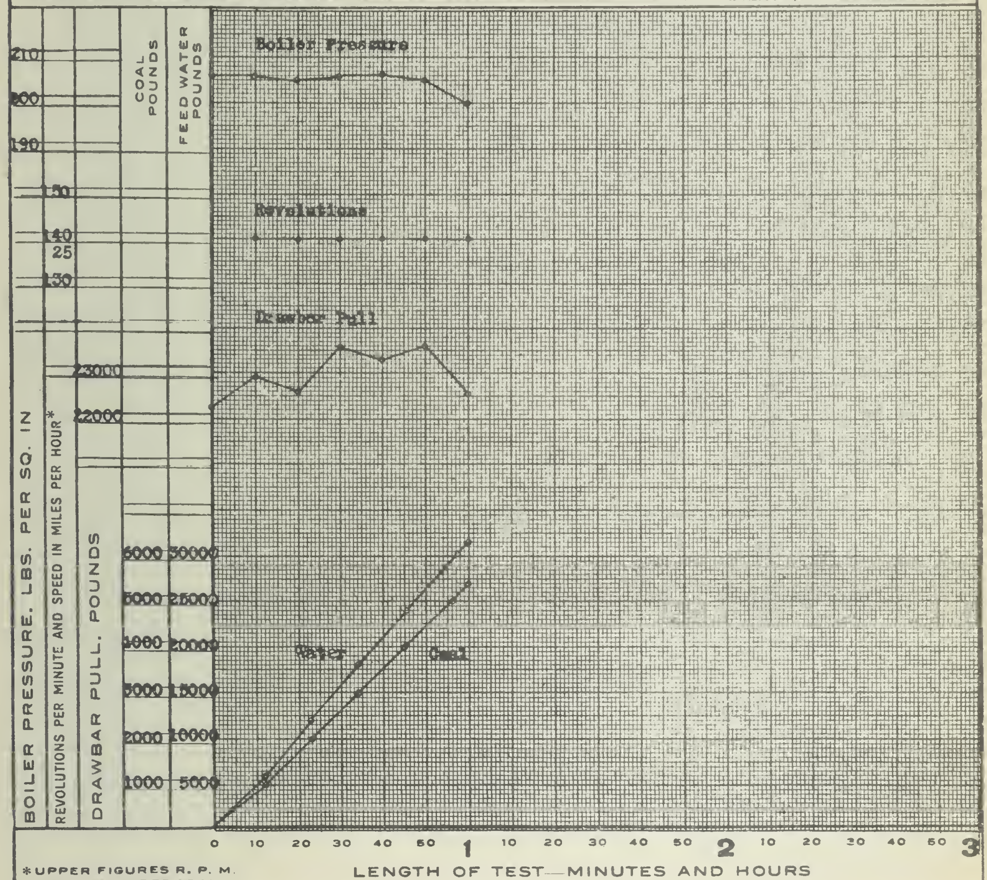
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-1223 TEST DEPARTMENT Bulletin NO. 10

GRAPHICAL LOG OF LOCOMOTIVE TEST

Tests of a Class H8sb Locomotive. ALTOONA, PA. 3-26-1913



*UPPER FIGURES R. P. M.
LOWER FIGURES APPROX.
SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 2-8-0
CLASS H8sb
NUMBER 387

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
25.2	140	40	F	5.9

TEST NO. 3220

SHEET NO. P-1223

M. P. Experimental D-1

12 9 1912
P x 10½

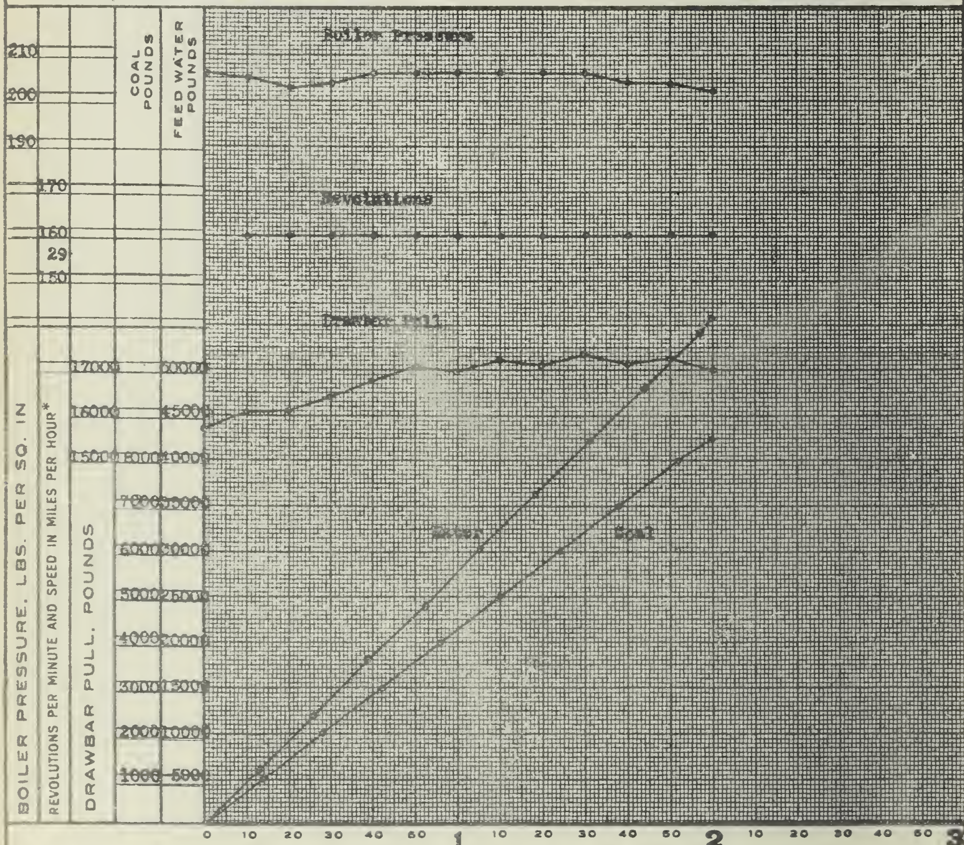
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-1224 TEST DEPARTMENT Bulletin NO. 10

GRAPHICAL LOG OF LOCOMOTIVE TEST

Tests of a Class H8sb Locomotive. ALTOONA, PA. 4-1-1913



LENGTH OF TEST —MINUTES AND HOURS

*UPPER FIGURES R. P. M.
LOWER FIGURES APPROX.
SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 2-8-0
CLASS H8sb
NUMBER 387

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
28.8	160	30	P	6.6

TEST NO. 8229

SHEET NO. P-1224

M. P. Experimental D-1

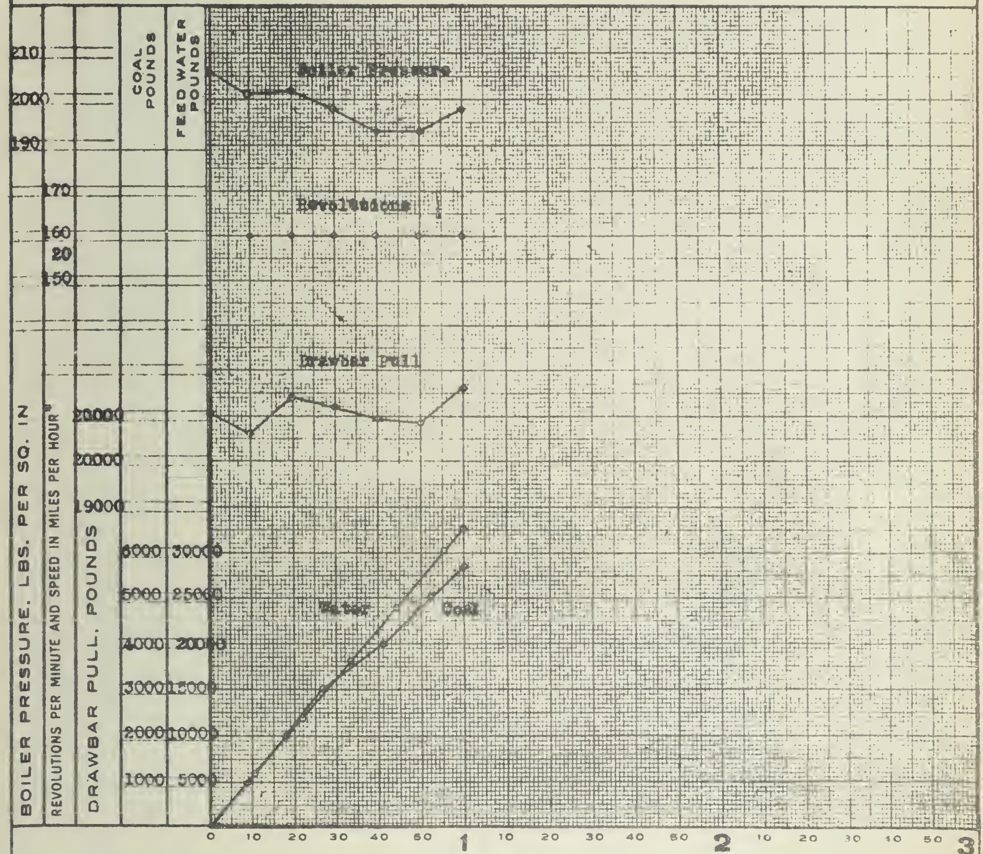
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-1225 | TEST DEPARTMENT | Bulletin NO 10

GRAPHICAL LOG OF LOCOMOTIVE TEST

Tests of a Class H8sb Locomotive | ALTOONA, PA. 4-4-1913



*UPPER FIGURES R. P. M
LOWER FIGURES APPROX.
SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 2-8-0
CLASS H8sb
NUMBER 387

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
28.8	160	40	F	5.7

TEST NO. 3235

SHEET NO. P-1225

M. P Experimental D-1

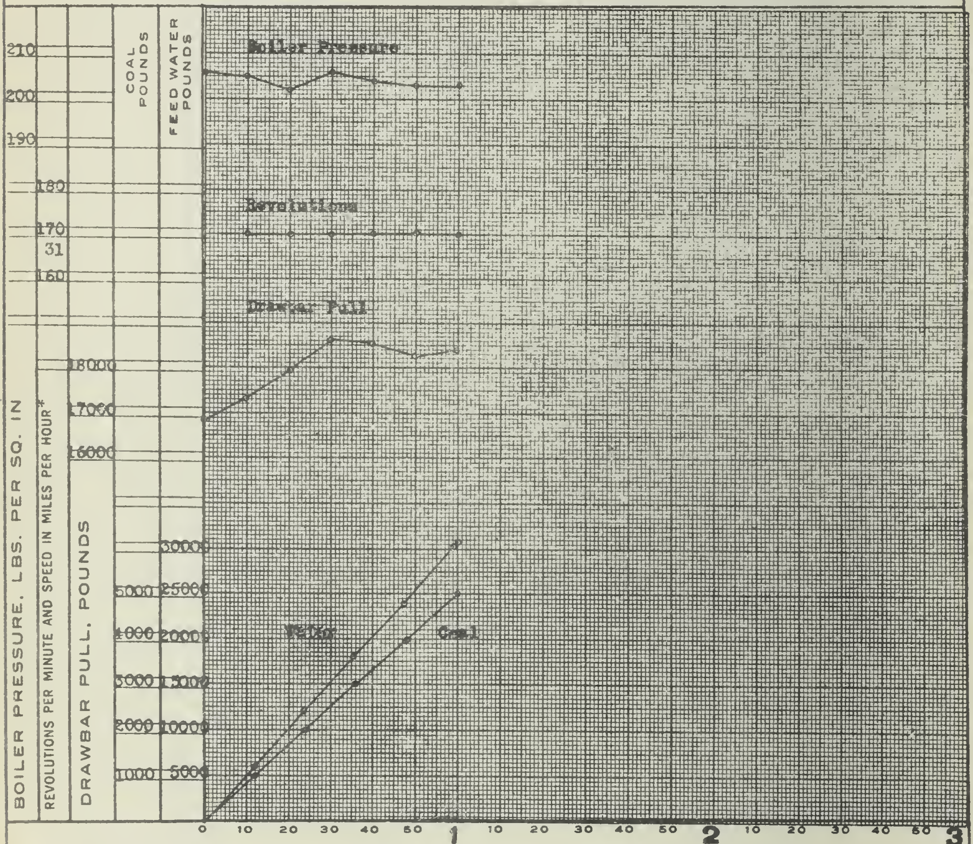
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO P-1226 TEST DEPARTMENT Bulletin NO 10

GRAPHICAL LOG OF LOCOMOTIVE TEST

Tests of a Class H8sb Locomotive. ALTOONA, PA 3-26-1913



LENGTH OF TEST—MINUTES AND HOURS

*UPPER FIGURES R. P. M.
LOWER FIGURES APPROX.
SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 2-8-0
CLASS H8sb
NUMBER 387

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
30.5	170	35	F	6.2

TEST NO. 3224

SHEET NO. P-1226

INDEX

The numbers refer to pages

V

W

PENNSYLVANIA RAILROAD COMPANY

Locomotive Testing Plant

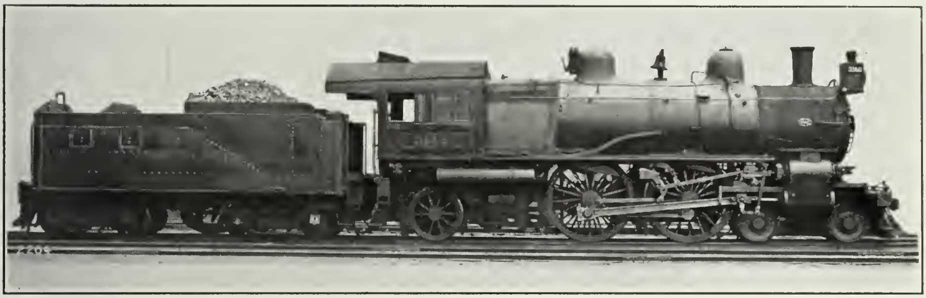
AT

ALTOONA, PENNA.

BULLETIN No. 11

TESTS OF A CLASS E3sd LOCOMOTIVE

1914



ATLANTIC TYPE LOCOMOTIVE No. 3162 (SATURATED STEAM).
Pennsylvania Railroad Class E2d.

ATLANTIC TYPE LOCOMOTIVE (SUPERHEATED STEAM).
Pennsylvania Railroad Class E3sd. A locomotive of the same class as No. 318, the one tested.

LOCOMOTIVE TESTING PLANT.

TESTS OF A CLASS E3sd PASSENGER LOCOMOTIVE.

Conclusions and Recommendations on pages 122 and 124,
Index on page 166.

TESTS OF ONE OF THE OLDER FORMS OF ATLANTIC TYPE PASSENGER LOCOMOTIVE WHICH HAS LATELY BEEN EQUIPPED WITH A SUPERHEATER AND COMPARISONS WITH A LOCOMOTIVE OF THE SAME TYPE USING SATURATED STEAM.

INTRODUCTION.

1. For the heavier passenger train service on many trunk line railroads, the tendency has been to substitute for the Atlantic type locomotive the heavier Pacific type, which can be constructed for greater power, but doubtless, there will continue to be many divisions on our own lines over which the operation of Pacific type locomotives need not be considered, and for service on these divisions the Atlantic type is especially well adapted. By the addition of the superheater to the older locomotives of this type, there is now a possibility of greatly increasing their capacity where a large capacity is needed, or increasing their economy where they work under moderate loads without necessitating any increase in the strength of the track structure over which they run.

2. With this fact in mind there has been a gradual conversion of Atlantic type saturated steam locomotives into superheater locomotives.

3. The tests described here were made on one of these converted Atlantic type locomotives of the E3sd class, No. 318, and a study of this Bulletin serves to show its improved performance over the class E2d saturated steam locomotive, due primarily to the application of the superheater.

4. The comparison is made with the E2d saturated locomotive No. 3162, which was previously tested on the Plant. At the time of the tests of this No. 3162, it was not equipped with an arch.

5. With the advent of the superheater and the use of the brick arch in the firebox, it was reasonable to assume that an increase in the capacity of this type of locomotive might easily be made; thus it could be adapted to still further use for heavy trains with fast schedules when operated on easy grades.

Description of the Locomotive.

6. Locomotive No. 318, the superheater locomotive, known as the E3sd class, is of the Atlantic type and has two simple cylinders. It is hand-fired and the superheater is of the Schmidt type. It is one of a number used in regular passenger service on the New York Division and was built at Juniata Shops, Altoona, Pa., in 1908. A superheater and an arch were added in 1912.

7. Before placing locomotive No. 318 on the test plant, it was taken into the shops and overhauled. The boiler was cleaned, tires turned and new tubes were put in. The machinery was put in good repair.

8. The locomotive was placed on the test plant and run for a time to get the bearing surfaces in good condition preparatory to the tests.

9. The general dimensions of the E3sd locomotive are as follows:

Total weight in working order, pounds	185400
Weight on drivers, working order, pounds	127900
Cylinders (simple) inches	22 x 26
Diameter of drivers, inches	80
Heating surface in tubes (water side) square feet	1836.10
Firebox heating surface, square feet including arch tubes	179.42
Heating surface of superheater, fire side, square feet	560.60
Total heating surface (based on fire side of firebox and water side of tubes) including arch pipes and superheater	2574.33
Total heating surface (based on fire side of firebox and tubes) including arch pipes and superheater	2381.52
Grate area, square feet	54.70
Boiler pressure, pounds per square inch	205
Valves, type	14 in. Piston
Valve motion	Walschaerts
Firebox, type	Wide, Belpaire
Number of tubes	170
Number of flues (for superheater)	24
Outside diameter of tubes, inches	2
Outside diameter of flues, inches	$5\frac{3}{8}$
Length of tubes, inches	179.71

10. The maximum calculated tractive effort at starting is 25,797 pounds with 80 per cent. of the boiler pressure available as mean effective pressure in the cylinders. This is equivalent to 157.3 pounds drawbar pull per pound of mean effective pressure. The ratio of weight on drivers to the calculated maximum tractive effort is 4.95.

General Arrangement.

11. The general arrangement of locomotive No. 318 is shown in Fig. 1. Cross-sections of it are shown in Fig. 2.

Boiler.

12. The boiler, Figs. 3 and 4, is of the Belpaire type. It has a wide grate, a sloping back head and throat sheet. In the firebox is a brick arch supported on three 3-inch water tubes. The feed water is delivered to the boiler through a pipe entering the back head, and extending inside the boiler to the front end. The heating surface (fireside) before the addition of the superheater was 2336 square feet. With the superheater in place the heating surface including the superheater is 2381 square feet. The total heating surface is therefore practically unchanged, by the application of the superheater, but the fire tube heating surface is decreased by about 530 square feet and replaced by about 560 square feet of superheating surface.

Grates.

13. The grate area of this locomotive is 54.70 square feet. The dimensions of the grate are approximately 6 feet wide and 9 feet 3 inches long. The interlocking finger type of shaking grate is used (see Fig. 5), and the grates are shaken in two separate sections.

14. When the locomotive came on the testing plant, there were stationary dead grates or blocked off sections at both the front and rear ends of the firebox. A few tests were made with the dead grates in position. With the idea of obtaining a better grate performance, the cement covering was removed from the dead grates. This increased the area of the air inlet openings 3.56 square feet. Drop grate sections are located at each end of the firebox between the finger grate section and the stationary grate sections. For tests of a similar arrangement of blocked off grates, see Bulletin No. 8, "Grate Area Reduced." With locomotive No. 318 there was a small increase in the maximum boiler capacity with the full grate in use.

15. The grates are supported in the center of the firebox by a cast-iron center grate bearer running longitudinally with the firebox.

16. The area of the active shaking portion of the grate was 28 square feet when tests were made. The drop grate sections cover an area of 15 square feet and the stationary live grates 11.7 square feet.

17. The ashpan is of the self-cleaning type, operated from the outside of the locomotive.

Superheater.

18. The boiler of locomotive No. 318 is equipped with a Schmidt type fire tube superheater with top header. There are 24 large flues, each of which contains a superheater unit.

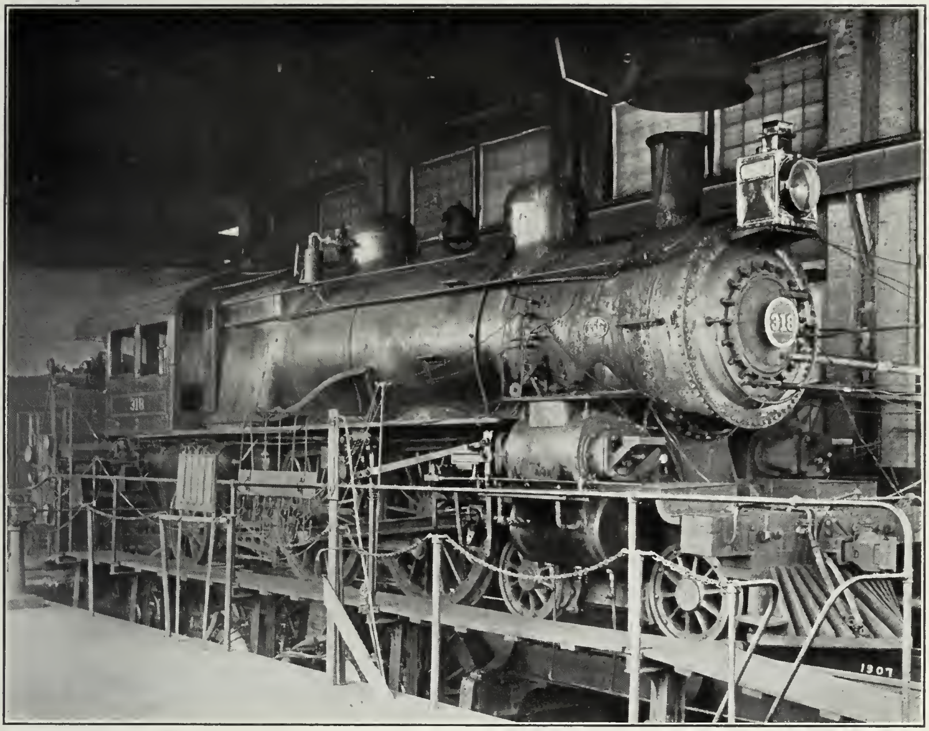
19. As shown in Fig. 6, the superheater unit extends from the saturated side of the superheater header back through the large flue to a point near the firebox end, thence, after making two passes through the large flue, it returns to the superheated side of the header. The outside diameter of the small tubes is 1.5 inches; the inside diameter of the large flues is 5.079 inches. The total area of the superheater is 560.60 square feet. The superheater heating surface forms 24 per cent. of the total heating surface of the boiler.

20. An automatically operated superheater damper is used to prevent the overheating of the superheater units when no steam is passing through them.

Smokebox.

21. A longitudinal section through the smokebox showing the arrangement of the draft appliances and netting is given in Fig. 6.

22. The smokebox is designed to be self-cleaning. The back portion of it is taken up by an enclosed superheater chamber, from the bottom of which a solid diaphragm plate extends down to the top of the exhaust pipe, thence the diaphragm extends out $7\frac{1}{2}$ inches beyond the center of the exhaust pipe. From this point a wire mesh netting extends at an angle to the top of the smokebox, covering the whole area.



LOCOMOTIVE No. 318, CLASS E3sd.
Locomotive Test Plant, Pennsylvania Railroad Company, Altoona, Pa.

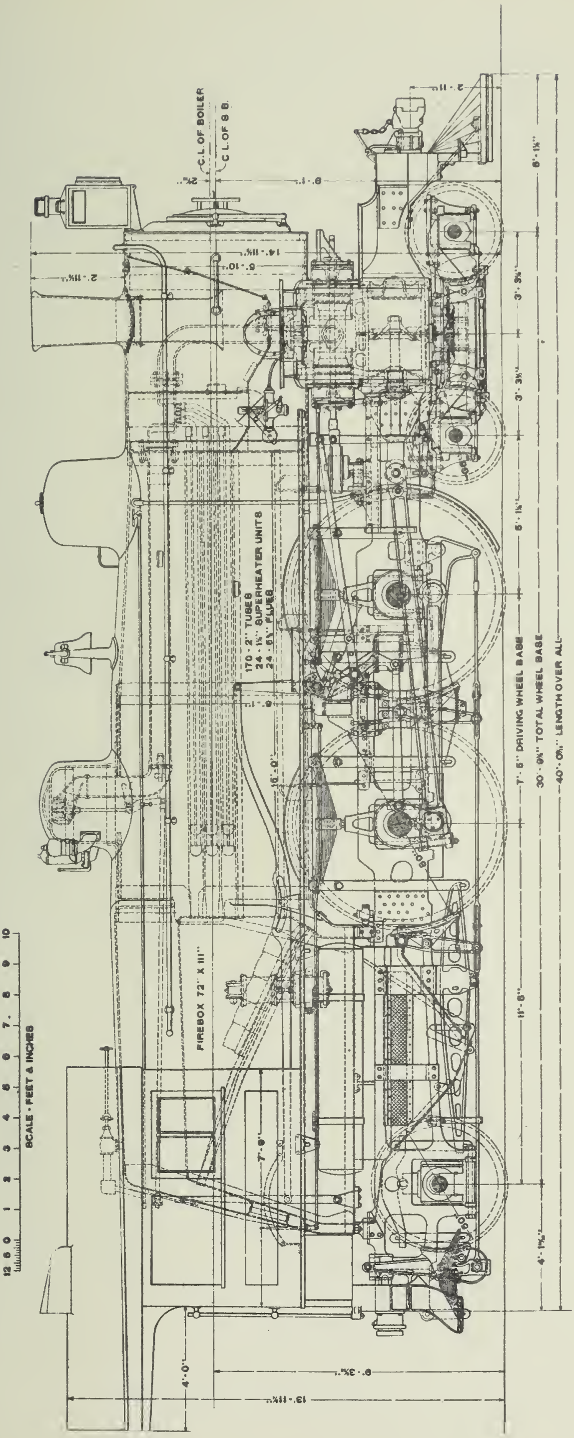


Fig. 1.
GENERAL ARRANGEMENT.
Class E3sd Locomotive No. 318.

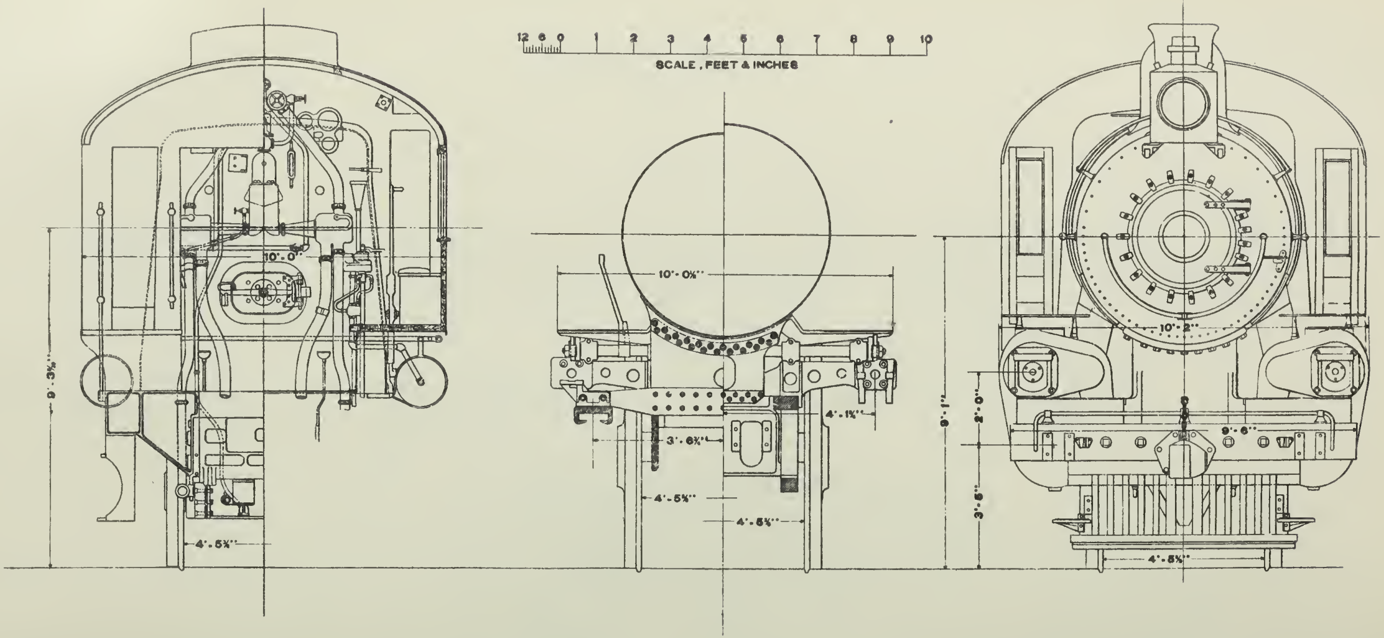


Fig. 2.
END ELEVATIONS AND CROSS SECTION
Class E3sd Locomotive No. 318.

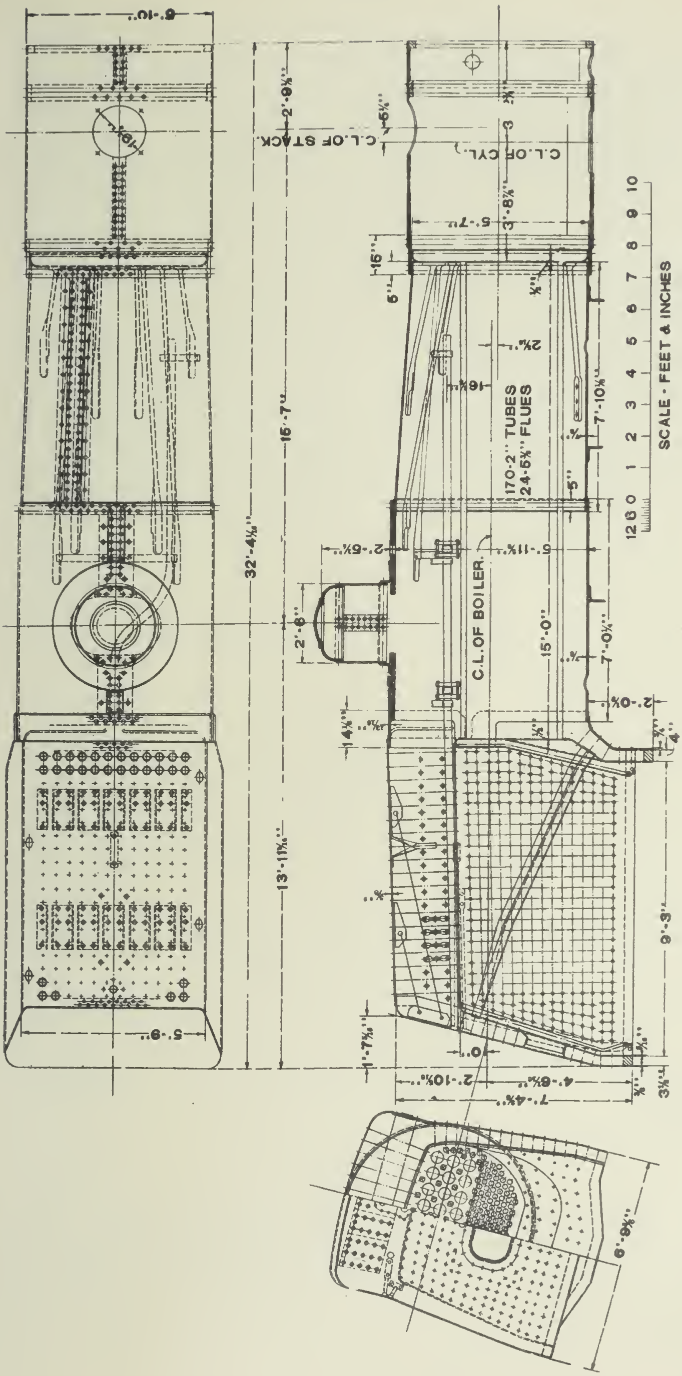


Fig. 3.
BOILER.
Class E3sd Locomotive No. 318.

23. The top of the exhaust nozzle is 14¾ inches below the horizontal center line of the boiler and 12 inches below the bottom of the lift pipe. The lift pipe (16 inches inside diameter), is 40¾ inches long, it terminates in the bottom of the stack which tapers to 18¾ inches in diameter at the top. The steam pipes are of the

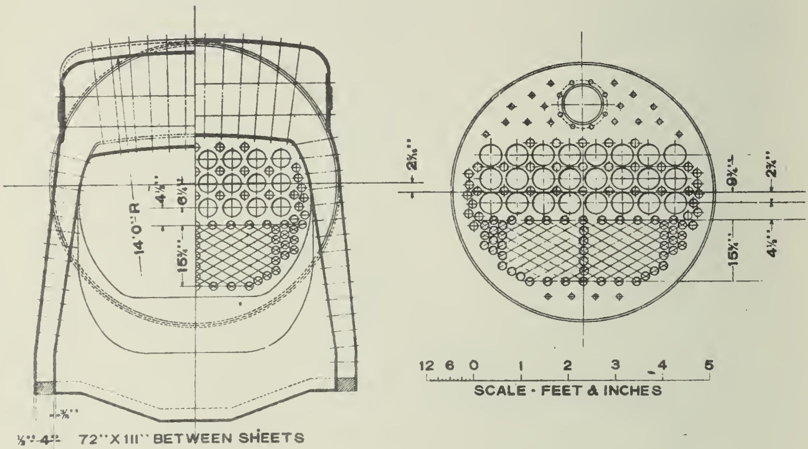


Fig. 4.
TUBE SHEETS.
Class E3sd Locomotive No. 318.

outside type, affording an unrestricted passage for the smokebox gases.

24. Tests were made with both rectangular and circular nozzles. The rectangular nozzle shown in Fig. 7, with an area of 25.44 square inches, was used in the tests from which the data presented in this Bulletin was derived, and with the smokebox arrangement, as shown in Fig. 6, very satisfactory results were obtained both in steaming and in discharging cinders from the smokebox.

Cylinders.

25. The cylinders (see Fig. 8) are made of cast iron. Their standard dimensions for this class of locomotive are 22 inches in diameter with a 26 inch stroke. The saddle and cylinder are cast in separate parts.

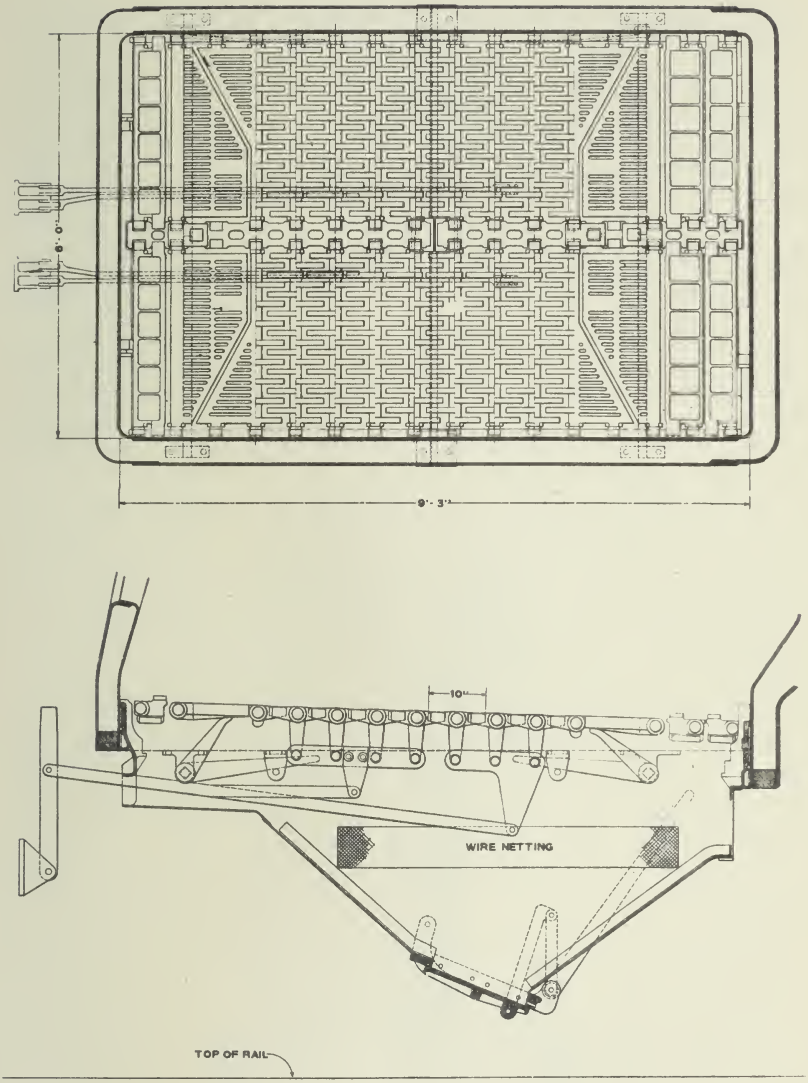


Fig. 5.
GRATE AND ASHPAN.
Class E3sd Locomotive No. 318.

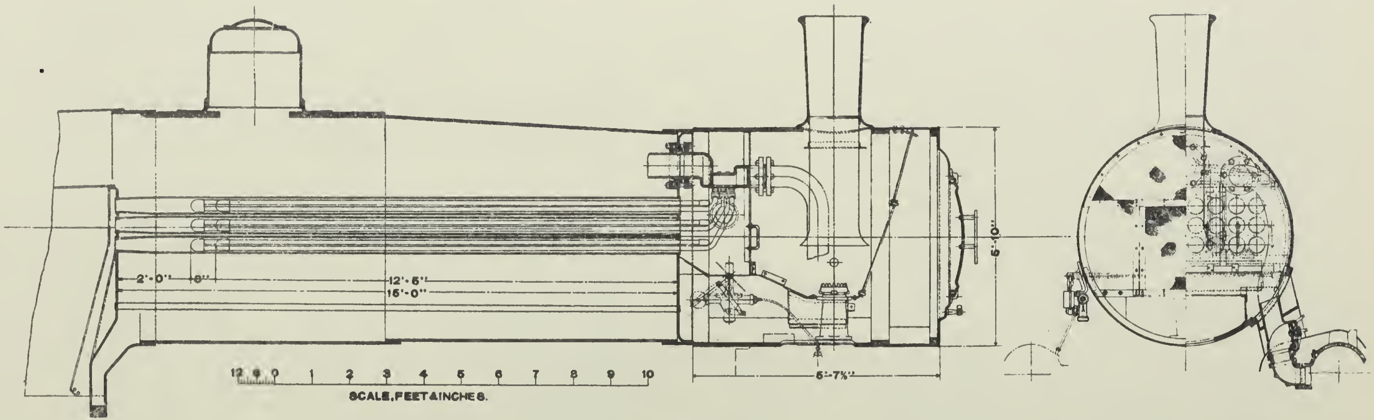


Fig. 6.
SUPERHEATER AND SMOKEBOX ARRANGEMENT.
Class E3sd Locomotive No. 318.

26. The steam pipes from superheater to cylinders pass through the side of the smokebox and connect at the side of the steam chest. The exhaust passage to the nozzle is indirect, containing a number of bends, some of which are of short radius.

27. The E3sd locomotive originally had a single steam pipe, but with the use of the outside form of steam pipe the connection of the single pipe to the cylinder saddle has been covered by a plate as shown in Fig. 8, and the steam no longer passes through the cylinder saddle.

28. The cylinders are designed for piston valves. The size of valve used is 14 inch. It has inside admission and is fitted with the "L" type of packing ring. This valve and valve cage are shown in Fig. 8-A.

29. While this locomotive was at the test plant, tests were made also with 7-inch diameter valves and 10-inch valves. The valve chambers were bushed in order to use these valves. These tests will be described in a separate Bulletin.

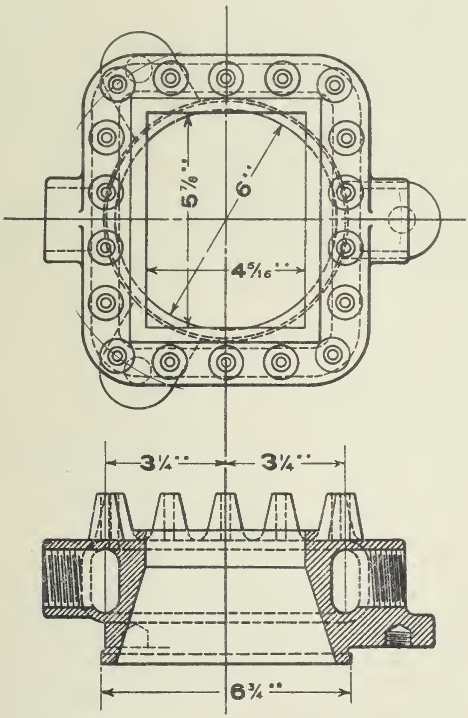


Fig. 7.
EXHAUST NOZZLE.

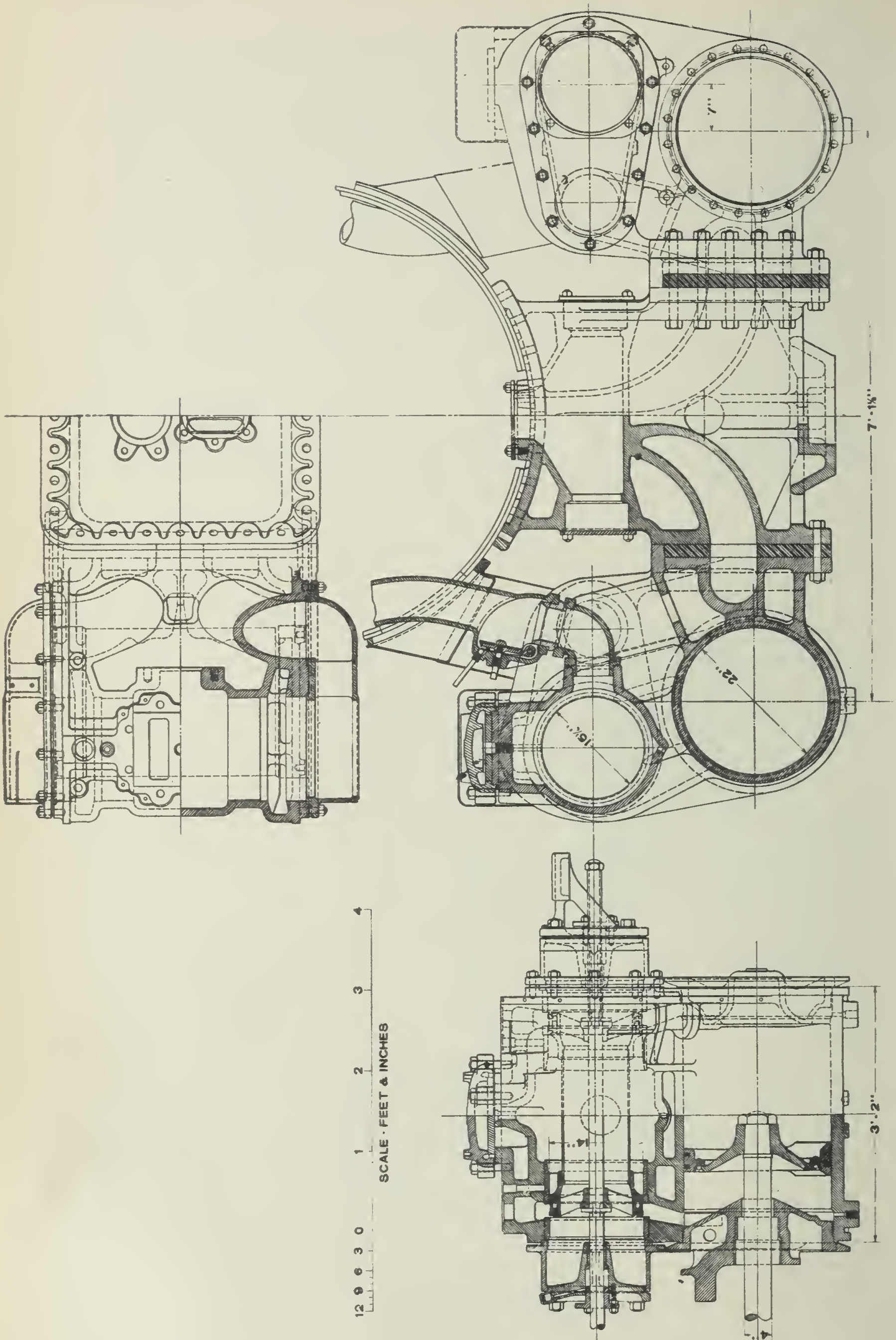


Fig. 8.
CYLINDERS.
Class E3sd Locomotive No. 318

Tests.

30. A total of 72 tests were made with the E3sd locomotive No. 318; most of these were for various special purposes.

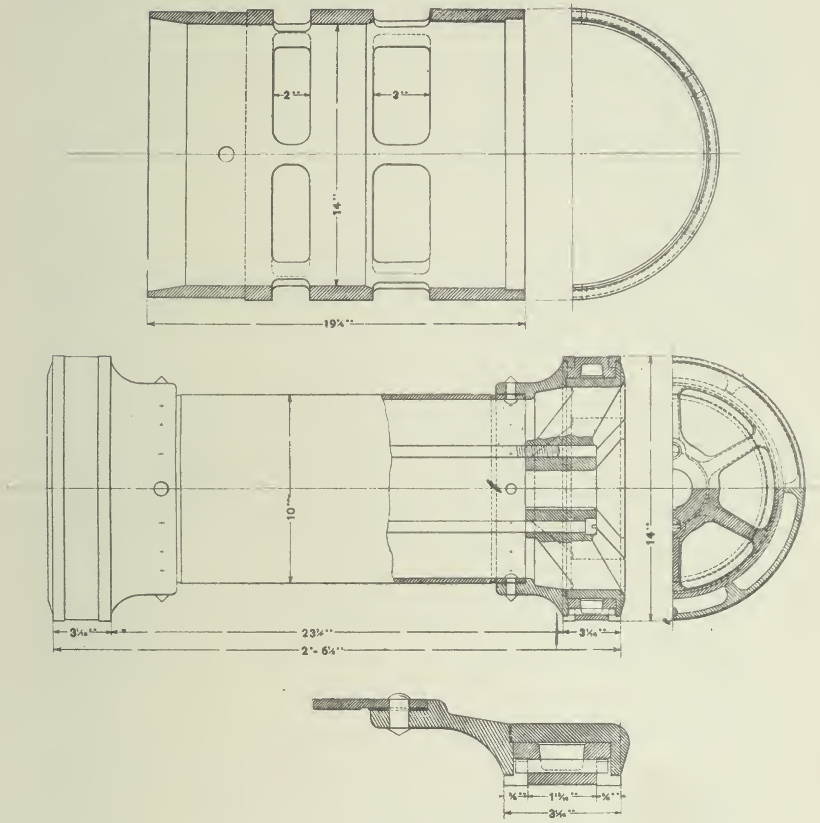


Fig. 8-A.
PISTON VALVE AND VALVE CAGE.
Class E3sd Locomotive No. 318.

31. In this Bulletin, the data is compiled from tests made with the locomotive in normal condition.

32. The tests to be considered are shown in the following table, together with their respective speeds from 28 to 84 miles per hour, with cut-offs varying from 20 to 50 per cent. and all run under a full throttle.

Full Throttle Tests, Locomotive No. 318, E3sd.

Revolutions per Minute r.p.m.	Miles Per Hour m.p.h.	Nominal Cut-off Per cent. of Stroke						
		20	25	30	35	40	45	50
120	28.01	1		1		1		
160	37.34			1	1		1	1
200	46.68	1			3		1	
240	56.02	1			1		2	
280	65.35	2			1			
320	74.69	1	1	1				
360	84.02		2					

33. The general conditions during the tests are shown in Tables I, II and III. Tables I and II are arranged according to the increase in speed and cut-off. Table III is arranged according to the rate of evaporation.

Coal Used.

34. A bituminous coal was used during these tests. It is mined by the Penn Gas Coal Company in the vicinity of Irwin, Pennsylvania, and is one of those used in passenger service on the Pennsylvania Railroad.

35. As is customary, test samples were taken from each car as it was being unloaded at the test plant. An average analysis of an air dried sample follows:

Proximate Analysis.

Fixed carbon, per cent	57.25
Volatile matter, per cent	34.46
Moisture, per cent	1.24
Ash, per cent	7.05
	100.00
Sulphur separately determined	1.82
B.t.u per pound of coal as received	14210
B.t.u per pound of coal, dry	14392
B.t.u in combustible	15550

Ultimate Analysis.

Carbon	79.19
Hydrogen	5.08
Nitrogen	1.53
Sulphur	1.62
Ash	6.36
Oxygen by difference	6.22
	100.00

BOILER PERFORMANCE.

STEAM PRESSURES AND TEMPERATURES.

36. The steam pressures by gage are given in Table I for the boiler, dry pipe, superheater header (saturated side) return bend, branch pipe and exhaust passage. The corresponding temperatures for boiler, branch pipe and exhaust passage are shown in Table II, together with the degree of superheat in the exhaust passage.

37. It will be observed that the boiler pressure throughout these tests was well maintained. In a majority of the tests it averaged around 205 pounds, while in a very few instances the pressure dropped to about 196 pounds.

38. The drop in pressure between dry pipe and branch pipe, or during its passage through the superheater, ranges from 2.9 pounds for light power tests to 18 pounds for maximum power tests.

39. The pressure in the exhaust passage varied from 2.4 pounds to 12.9 pounds. The latter pressure was observed at the maximum evaporation rate of 14.5 pounds per square foot of heating surface.

40. It is interesting to note the pressure, together with the range of temperature and superheat at the different rates of firing. Referring to Fig. 9, it is seen that the temperature of steam in the branch pipe increased from 505 degrees Fahr. to 632 degrees, while the rate of firing increased from 31 to 109 pounds per hour per square foot of grate.

41. Meanwhile the superheat in the exhaust passage increased from 6.4 to 83 degrees Fahr. The latter figure was attained during the maximum rate of combustion and is somewhat higher than the superheat in the exhaust passage of the E6s locomotive No. 89 (see Bulletin No. 21, Table II).

M. P. 479—A

8 x 10½
351 4-29-12

LOCOMOTIVE:
TYPE 4-4-2
CLASS E3sd No. 318

PENNSYLVANIA RAILROAD COMPANY
PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

TEST DEPARTMENT

Bulletin No. 11

SHEET NO. P-1052

Tests of a Class E3sd Locomotive. ALTOONA, PA. 11-1-1913

STEAM PRESSURE

Test No.	Test Designation	Duration of Test Minutes	Steam Pressure by Gauge In					
			Boiler	Dry Pipe	Superheater Header Saturated Side	Return Bend	Branch Pipe	Exhaust Passage
			217				220	
3111	120-20-F	120	203.6	201.1	200.3	199.9	198.2	2.4
3112	120-30-F	120	205.2	203.3	202.5	200.6	199.2	2.8
3137	120-40-F	120	206.0	206.0	204.8	201.0	198.0	4.2
3121	160-30-F	120	205.5	204.8	202.8	201.2	196.5	4.2
3113	160-35-F	120	205.5	204.3	203.3	199.4	197.2	5.3
3114	160-45-F	90	205.5	203.6	203.5	198.4	192.6	8.3
3133	160-50-F	60	203.4	203.4	201.7	197.4	189.3	9.4
3136	200-20-F	120	205.8	205.8	203.6	201.3	198.8	3.5
3115	200-35-F	120	205.0	203.5	202.7	199.4	193.2	6.8
3134	200-35-F	60	205.1	205.1	202.9	200.6	193.0	6.7
3135	200-35-F	60	206.0	206.0	204.3	201.4	194.7	6.5
3124	200-45-F	90	203.0	202.9	201.2	196.5	186.0	11.5
3117	240-20-F	120	206.0	204.8	202.8	202.4	198.8	4.4
3116	240-35-F	90	205.4	203.6	202.4	200.2	192.7	7.8
3109	240-45-F	60	195.9	193.4	191.9	186.9	175.6	12.9
3139	240-45-F	60	196.4	196.4	193.7	189.1	178.0	12.7
3119	280-20-F	90	206.0	205.6	203.9	202.3	197.4	5.0
3122	280-30-F	60	197.1	197.0	194.0	191.2	185.4	7.3
3125	280-35-F	60	205.7	205.3	203.0	199.3	191.1	9.9
3126	320-20-F	60	205.6	205.6	203.1	201.1	195.1	6.1
3128	320-25-F	60	205.9	205.9	203.3	200.8	195.0	7.4
3127	320-30-F	60	204.5	203.8	201.2	198.3	190.8	9.3
3142	360-25-F	30	196.8	196.8	196.0	190.9	184.5	7.8
3143	360-25-F	30	205.8	205.8	201.8	198.3	191.0	8.8

SHEET NO. P-1052

Table I.
STEAM PRESSURE.
The steam pressure between the boiler and exhaust passage.

M. P. 479—A

8 x 10½
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LOCOMOTIVE:
TYPE 4-4-2
CLASS E3sd No. 318

SHEET No. P-1053

PENNSYLVANIA RAILROAD COMPANY
PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY
TEST DEPARTMENT

Bulletin No. 11

Tests of a Class E3sd Locomotive. ALTOONA, PA. 11-1-1913

STEAM TEMPERATURE

Test No.	Test Designation	Duration of Test Minutes	Temperature in Boiler	Temperature in Branch Pipe	Temperature in Exhaust Passage	Superheat In Exhaust Passage
3111	120-20-F	120	389.1	505.2	225.8	6.4
3112	120-30-F	120	389.7	525.8	229.8	10.4
3137	120-40-F	120	389.9	579.4	248.6	26.2
3121	160-30-F	120	389.7	585.7	250.5	28.1
3113	160-35-F	120	389.8	548.2	247.5	19.5
3114	160-45-F	90	389.7	559.8	276.1	45.5
3133	160-50-F	60	388.9	594.9	297.1	61.6
3136	200-20-F	120	389.9	582.6	231.8	9.4
3115	200-35-F	120	389.5	564.2	248.9	18.3
3134	200-35-F	60	389.6	602.9	265.1	34.5
3135	200-35-F	60	389.9	612.9	276.9	46.3
3124	200-45-F	90	388.8	614.4	300.2	58.6
3117	240-20-F	120	390.0	595.7	244.6	19.4
3116	240-35-F	90	389.9	598.8	272.6	39.5
3109	240-45-F	60	385.9	570.9	306.3	61.9
3139	240-45-F	60	386.1	632.3	327.4	83.0
3119	280-20-F	90	390.0	607.8	260.4	35.2
3122	280-30-F	60	386.4	609.1	280.9	47.8
3125	280-35-F	60	389.9	610.9	281.1	43.3
3126	320-20-F	60	389.7	593.1	258.0	30.0
3128	320-25-F	60	389.9	607.1	272.3	39.2
3127	320-30-F	60	389.3	612.3	283.0	46.3
3142	360-25-F	30	386.2	602.0	286.0	52.9
3143	360-25-F	30	389.8	605.5	284.0	48.5

SHEET No. P-1053

Table II.
STEAM TEMPERATURES.
These steam temperatures correspond with the pressures as shown in Table I, except for the temperature of the boiler steam, which is taken from a steam table.

M. P. 479—A

8 x 10½
351 4-29-12

LOCOMOTIVE:
TYPE 4-4-2
CLASS E3sd No. 318

SHEET No. P-1054

PENNSYLVANIA RAILROAD COMPANY
PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY
TEST DEPARTMENT

Bulletin No. 11

Tests of a Class E3sd Locomotive.

ALTOONA, PA. 11-1-1913

COMBUSTION, GENERAL CONDITIONS.

Test No.	Test Designation	Duration of Test Mins.	Average Pressure in lb. per sq. in.		Temperature Degrees Fahr.		Dry Coal Fired per Hour lb. per sq. ft. of Grate surface	Total Water Evap. lb. per hour per sq. ft. of heating surface	Ratio column 339 to 342
			Boiler Pressure	Atmospheric Pressure	Testing Plant	Feed Water			
			217	221	208	211	339	342	
3111	120-20-F	120	203.6	14.42	58	43.7	31.19	6.35	4.911
3112	120-30-F	120	205.2	14.38	50	43.8	40.95	7.56	6.547
3136	200-20-F	120	205.8	14.09	61	43.1	44.83	8.08	5.977
3121	160-30-F	120	205.5	14.27	64	41.7	46.20	8.58	5.384
3117	240-20-F	120	206.0	14.34	54	42.0	49.80	8.81	5.652
3137	120-40-F	120	206.0	14.10	56	43.3	53.78	8.94	6.015
3119	280-20-F	90	206.0	14.39	55	42.0	58.85	9.69	6.073
3113	160-35-F	120	205.5	14.29	49	42.3	53.93	9.95	5.420
3136	320-20-F	60	205.6	14.08	63	43.0	69.05	10.50	6.576
3135	200-35-F	60	206.0	14.13	60	43.3	66.97	10.73	6.241
3134	200-35-F	60	205.1	14.15	62	44.0	81.85	10.98	7.454
3115	200-35-F	120	205.0	14.14	54	42.0	73.89	11.27	6.556
3122	280-30-F	60	197.1	14.23	63	42.0	78.87	11.14	7.079
3142	360-25-F	30	196.8	13.93	59	42.0	93.93	11.71	8.021
3128	320-25-F	60	205.9	14.25	67	44.0	75.11	11.74	6.397
3116	240-35-F	90	205.4	14.39	48	43.8	80.35	12.11	6.635
3143	360-25-F	30	205.8	14.08	59	43.0	99.52	12.30	8.091
3114	160-45-F	90	205.5	14.23	56	42.0	89.36	12.53	7.131
3127	320-30-F	60	204.5	14.23	64	44.7	102.67	12.44	8.253
3133	160-50-F	60	203.4	14.02	58	42.2	100.57	12.83	7.838
3125	280-35-F	60	205.7	14.16	55	44.3	89.87	13.23	6.792
3124	200-45-F	90	203.0	14.04	64	43.9	100.38	13.71	7.295
3109	240-45-F	60	195.9	14.04	58	44.0	104.26	14.53	7.175
3139	240-45-F	60	196.4	13.92	59	43.0	109.27	14.21	7.689

SHEET No. P-1054

Table III.

COMBUSTION, GENERAL CONDITIONS.

The tests in this table are arranged according to the increase in evaporation. As the maximum evaporation is reached the boiler pressure, column 217, cannot be maintained, as is shown by the low average pressures in the last tests.

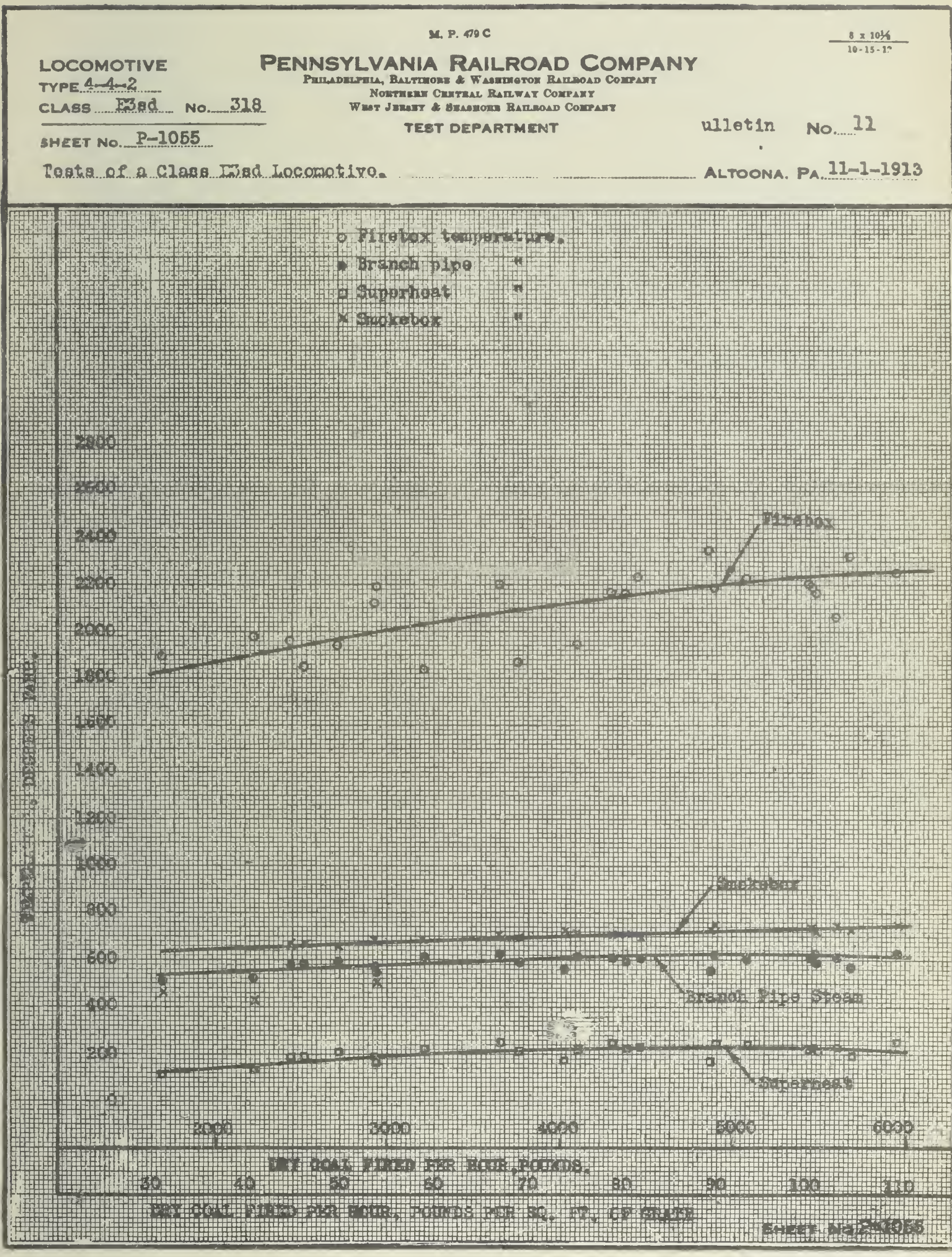

Fig. 9.

FIREBOX AND SMOKEBOX TEMPERATURES.

This diagram also shows the temperature of the superheat and of the steam in the branch pipe. The steam after being superheated is at a lower temperature than that of the smokebox through which it passes.

Draft.

42. The draft in inches of water given in Table IV is shown at four points: in front of diaphragm, back of diaphragm, in firebox and in ashpan. The draft at the maximum rate of firing was 12.8 inches of water in front of diaphragm, 9.1 inches back of diaphragm, 2.5 inches in firebox and 0.21 inches in ashpan. The corresponding rate of combustion was 109.27 pounds of dry coal per square foot of grate per hour.

43. In order to present more clearly the relation between the draft and the combustion for this locomotive, curves are shown in Fig. 10. Here the ordinates represent the draft in inches of water. The abscissae indicate the combustion rate, or the pounds of dry coal fired per square foot of grate per hour. The increase in draft follows a straight line in each instance. The distance between the curves represents the loss of draft. At the maximum rate of combustion the loss of draft between front and back of diaphragm was 29 per cent., between firebox and diaphragm 51 per cent., and 20 per cent. is the loss between ashpan and firebox.

44. The firebox temperature shows a gradual increase with an increase in the combustion rate. At the same time the temperature of the gases in the smokebox, and of the steam in the branch pipes shows a smaller increase.

45. It is observed that an increase in the draft has a more pronounced effect upon the firebox temperature than upon either of the other two temperatures.

46. Attention is also called to the difference in temperature between the smokebox gases and the superheated steam in the branch pipes. It is apparent that the temperature of the smokebox gases is higher than the steam temperature throughout the whole range of combustion by approximately 80 degrees Fahr. and that this difference is practically constant throughout.

47. Consequently the boiler is not absorbing this heat which could be utilized to attain a higher degree of superheat, and is no doubt due to the length of tube. With longer tubes the boiler would absorb a portion of the heat. On the other hand, if we lengthen the tubes and probably increase the efficiency of the boiler somewhat, we would at the same time impair its free steaming qualities, by restrictions upon the activity of combustion and rapidity of evaporation. This subject is further considered under "Boiler Tube Temperature," Pars. 96 to 110, inclusive.

M. P. 479—A

8 x 10½
301 4-29-12

LOCOMOTIVE
TYPE 4-4-2
CLASS E3sd NO. 318

PENNSYLVANIA RAILROAD COMPANY
PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY
TEST DEPARTMENT

Bulletin NO. 11

SHEET NO. P-1056

Tests of a Class E3sd Locomotive. ALTOONA, PA. 11-1-1913

COMBUSTION, DRAFT & TEMPERATURE

Test No.	Test Designation	Duration of Test Mins.	Draft in Inches of Water				Temperature Degrees Fahr.			Coal as Fired per sq.ft. of grate Pounds per Hour
			In Front of Diaphragm	Back of Diaphragm	In Fire box	In Ash pan	In Fire box	In Smoke box	of Steam in Branch Pipe	
			222	223	224	225	212	207	210	
3111	120-20-F	120	3.3	2.0	0.4	0.08	1897	471	505.2	31.72
3112	120-30-F	120	4.4	2.7	0.4	0.12	1979	433	525.8	41.64
3136	200-20-F	120	4.6	2.9	0.8	0.06	1962	673	582.6	91.41
3121	160-30-F	120	5.9	4.1	1.0	0.15	1852	669	585.7	46.07
3117	240-20-F	120	6.0	4.3	1.1	0.12	1940	560	595.7	50.66
3137	120-40-F	120	5.7	4.3	1.3	0.08	2122	691	579.4	54.84
3119	280-20-F	90	7.6	5.4	1.4	0.10	1838	688	607.8	59.87
3113	160-35-F	120	7.2	5.1	0.7	0.18	2197	500	548.2	54.84
3126	320-20-F	60	8.0	6.0	2.0	0.11	1871	699	593.1	70.24
3135	200-35-F	60	8.0	5.6	1.7	0.12	2200	703	612.9	68.29
3134	200-35-F	60	8.3	5.8	1.8	0.13	2235	699	602.9	63.47
3115	200-35-F	120	9.3	7.0	1.3	0.23	-	725	564.2	75.15
3122	280-30-F	60	10.3	8.0	2.6	0.27	2164	712	609.1	80.22
3142	360-25-F	30	9.8	7.2	3.3	0.11	2224	-	602.0	95.79
3128	320-25-F	60	9.3	6.7	1.7	0.13	1922	718	607.1	76.59
3116	240-35-F	90	9.9	7.4	2.4	0.30	2163	711	598.8	81.74
3143	360-25-F	30	10.5	7.6	3.1	0.13	2206	-	605.5	101.28
3114	160-45-F	90	10.9	8.2	1.2	0.30	2348	736	559.8	90.88
3127	320-30-F	60	11.4	8.6	2.4	0.13	2063	743	612.3	104.72
3133	160-50-F	60	10.6	7.9	2.4	0.16	2170	722	594.9	102.56
3125	280-35-F	60	11.3	8.2	2.1	0.24	2197	728	610.9	91.41
3124	200-45-F	90	12.3	8.8	2.6	0.34	2188	734	614.4	102.01
3109	240-45-F	60	13.7	9.8	1.6	0.41	2322	730	570.9	106.03
3139	240-45-F	60	12.8	9.1	2.5	0.21	2249	748	632.3	111.44

SHEET NO. P-1056

Table IV.

COMBUSTION DRAFT AND TEMPERATURE.

The draft figures in this table are plotted in Figs. 10 and 15.

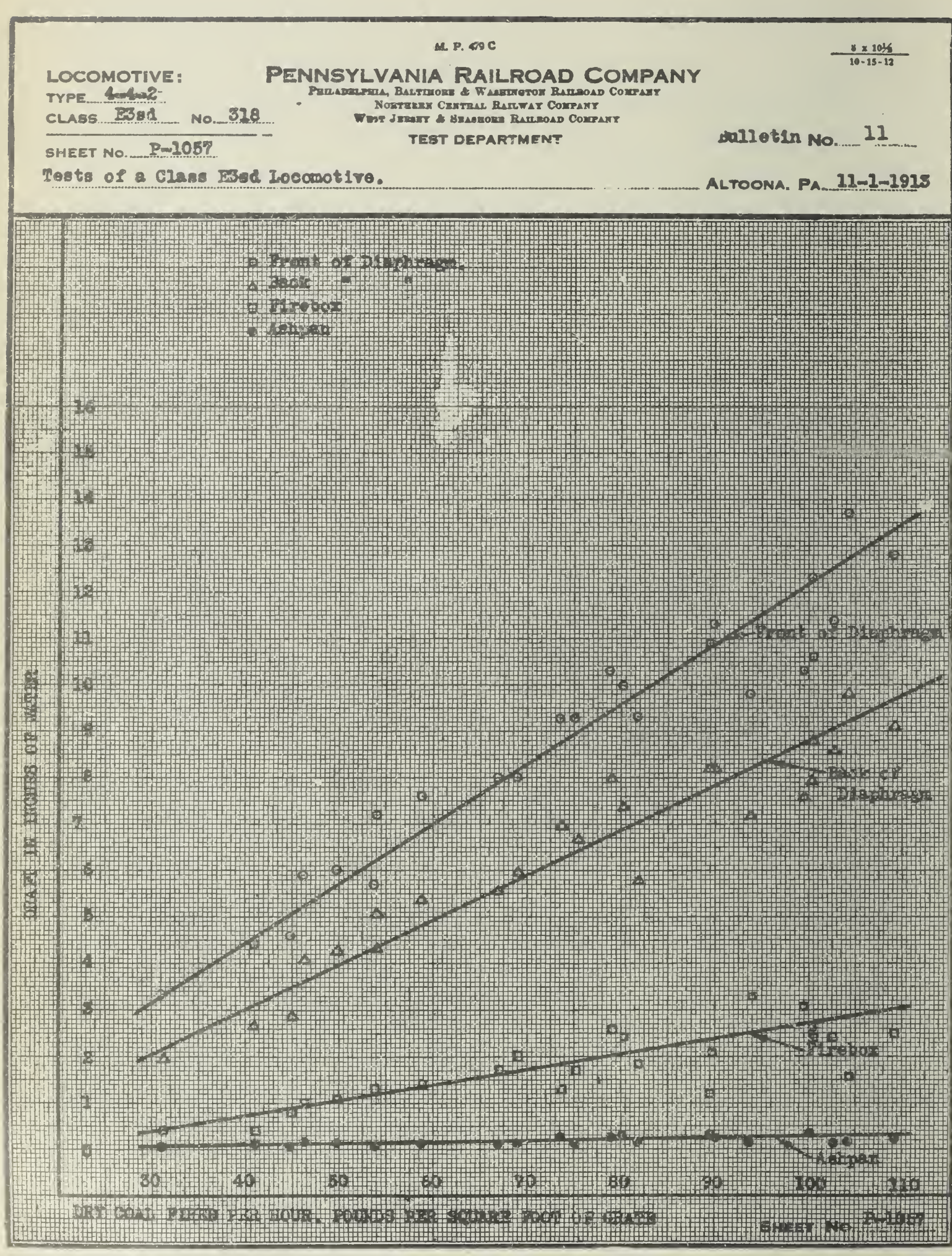

Fig. 10.

DRAFT AND RATE OF COAL BURNING.

The maximum draft in the smokebox is nearly 14 inches, the reduction in draft between the front and back of diaphragm is about 27.4 per cent. when working at the maximum rate.

Combustion Rate and Heat Transfer.

48. The rate of combustion (Table III, column 339), ranged from 31.19 to 109.27 pounds of dry coal per hour per square foot of grate. Some tests were made on locomotive No. 3162, class E2d, using Penn gas coal, and comparing its rate of combustion with that of the superheated steam locomotive presented here at a speed of 200 r.p.m. (47 m.p.h.) with a cut-off of 35 per cent. and a wide open throttle, we find that the E2d or saturated locomotive burned 53 per cent. more coal; evaporated 26.3 per cent. more water, but developed only 78.6 per cent. of the draw-bar pull obtained from the superheated steam locomotive. As shown in Fig. 10 the rate of combustion of the E3sd increased regularly with the draft. The points all lie close to their respective average curves.

49. The dry coal consumed per square foot of heating surface per hour ranged from 0.716 to 2.509 pounds.

50. It was shown in Fig. 9 that as the rate of combustion increased from minimum to maximum, there was a gradual increase in the temperature of the firebox and smokebox. This was also true in the case of the branch pipe temperature, and the superheat until the rate of combustion reached 80 pounds of dry coal per square foot of grate per hour, these temperatures then remained stationary up to a rate of combustion of 100 pounds per square foot of grate per hour. Thereupon the branch pipe temperature and superheat decreased gradually.

51. That approximately one-tenth of the heat absorbed is taken up by the superheater surface is shown in Table V.

52. When burning the greatest weight of coal per hour, the temperature of the firebox, as measured by a thermo-couple, reached 2249 degrees Fahrenheit (Table IV, column 212), and the temperature of the smokebox gases was 748 degrees (column 207), showing that the difference, or 1501 degrees temperature drop, must have been caused by heat absorbed by the boiler. At different rates of combustion this drop varied considerably, but the average was 1415 degrees for all of the tests.

M. P. 479—A

8 x 10½
351 4-29-12

LOCOMOTIVE:
TYPE 4-4-2
CLASS E3sd No. 318

PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

TEST DEPARTMENT

Bulletin No. 11

SHEET NO. P-1058

Tests of a Class E3sd Locomotive. ALTOONA, PA. 11-1-1913

RATE OF COMBUSTION AND HEAT TRANSFER

Test No.	Test Designation	Duration of Test Mins.	Total Dry Coal Fired	Dry Coal Fired Per Hour	Rate of Combustion: Dry Coal Fired per Sq.ft.of Grate per hr.	Rate of Combustion: Dry Coal Per Sq.ft.of Heating surface Per hour	Heat Transfered across Water Heating Surface B.t.u. Per minute	Heat Transfered across superheating surface B.t.u. Per Minute
			235	338	329			
3111	120-20-F	120	3412	1706	31.19	0.716	299473	20007
3112	120-30-F	120	4479	2240	40.95	0.941	356584	27033
3136	200-20-F	120	4903	2452	44.83	1.030	381406	37346
3121	160-30-F	120	5053	2527	46.20	1.061	405117	40256
3117	240-20-F	120	5448	2724	49.80	1.144	415792	43211
3137	120-40-F	120	5883	2942	53.78	1.235	421963	40813
3119	280-20-F	90	4829	3219	58.85	1.352	457164	47844
3113	160-35-F	120	5899	2950	53.93	1.239	469828	39247
3126	320-20-F	60	3777	3777	69.05	1.586	495110	50046
3135	200-35-F	60	3663	3663	66.97	1.538	506373	56540
3134	200-35-F	60	4477	4477	81.85	1.879	517373	53872
3115	200-35-F	120	8083	4042	73.89	1.697	531926	46516
3122	280-30-F	60	4314	4314	78.85	1.811	525674	58024
3142	360-25-F	30	2569	5138	93.93	2.157	551864	59623
3128	320-25-F	60	4108	4108	75.11	1.725	553527	59988
3116	240-35-F	90	6593	4395	80.35	1.845	570710	60879
3143	360-25-F	30	2722	5444	99.52	2.286	580389	62262
3114	160-45-F	90	7332	4888	89.36	2.052	591661	52572
3127	320-30-F	60	5616	5616	102.67	2.358	585839	66180
3133	160-50-F	60	5501	5501	100.57	2.309	605750	62657
3125	280-35-F	60	4916	4916	89.87	2.064	623810	69379
3124	200-45-F	90	8236	5491	100.38	2.305	648328	73506
3109	240-45-F	60	5703	5703	104.26	2.395	684600	66601
3139	240-45-F	60	5977	5977	109.27	2.509	670105	80482

SHEET NO. P-1058

Table V.

RATE OF COMBUSTION AND HEAT TRANSFER.

This table shows the rate of combustion or the dry coal fired per hour per square foot of grate surface. It also shows the heat transferred across the water and superheating surfaces in heat units per minute.

Ashpan, Air Inlets.

53. During some of the tests, locomotive No. 318 did not seem to have a very active combustion at the rear of the firebox. The draft was apparently sufficient. To ascertain just what effect it would have on the fire, the rear row of brick was removed from the arch and a test was made at 200 r.p.m. with a 50 per cent. cut-off and a wide open throttle. Its duration was 20 minutes and while the average boiler pressure was low, an evaporation of 36,144 pounds of water per hour was obtained, which is much better than that obtained during a test under like conditions, Test No. 3109, namely: 34,737 pounds.

54. Test 3133 was then run at 160 r.p.m. with 50 per cent. cut-off and throttle wide open, in comparison with test No. 3131, which is not recorded in this Bulletin. On account of low pressure, the evaporation rate was increased from 27,096 pounds to 30,691 pounds per hour. The only reason for the improved performance of the locomotive during this test, that was discernible, aside from the change to the arch, was the fact that the ashpan door was open.

55. The area of all of the present air inlet openings in the ashpan of this locomotive with the door closed is 6.54 square feet or 12 per cent. of the grate area, and this appears to be too small.

Smokebox Gases.

56. The analysis of the smokebox gases is given in Table VI, columns 253 to 256 inclusive. The loss due to carbon monoxide was comparatively small, ranging from 0.0 in some instances to 3.3 per cent., the amount at the greatest rate of combustion.

57. The smoke, according to the Ringelmann scale, varied from 8 to 46 per cent. The locomotive was hand-fired and the smoke can be considered as moderately low compared with other tests on the plant. This is no doubt due to the presence of the brick arch in the firebox, enabling a portion of the smoke to be consumed. A low percentage of smoke was accompanied by a high boiler efficiency.

M. P. 479—A

8 x 10½
351 4-29-12

LOCOMOTIVE:
TYPE 4-4-2
CLASS E3sd No. 318

SHEET No. P-1059

PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

TEST DEPARTMENT

Bulletin No. 11

Tests of a Class E3sd Locomotive. ALTOONA, PA. 11-1-1913

SMOKEBOX GASES

Test No.	Test Designation	Duration of Test, Mins.	Analysis of Smokebox Gases: Oxygen, O Per cent	Carbon Monoxide, C O Per cent	Carbon Dioxide, CO2 Percent	Nitrogen, N Percent	Calorific Value of Dry Coal, B. T. U. per pound	Percent of heat in Coal lost by presence of C O	Temperature of Smoke Box	Smoke, Percent, Ringelmann Scale
			253	254	255	256	248		207	
3111	120-20-F	120	5.4	0.0	12.6	82.0	14442	0	471	8
3112	120-30-F	120	4.2	0.0	13.0	82.7	14442	0	433	10
3136	200-20-F	120	3.8	0.3	13.8	82.1	14581	1.10	673	14
3121	160-30-F	120	3.0	0.3	14.5	82.2	14266	1.63	736	16
3117	240-20-F	120	4.6	0.0	13.6	81.8	14266	0	660	20
3137	120-40-F	120	4.0	0.4	13.2	82.3	14581	1.59	691	16
3119	280-20-F	90	1.8	1.0	14.0	83.2	14266	3.71	688	28
3113	160-35-F	120	2.8	0.4	14.3	82.6	14442	1.44	500	14
3126	320-20-F	60	3.6	0.3	13.1	83.0	14266	1.24	699	16
3135	200-35-F	60	1.3	1.[illegible]	14.7	82.7	14581	4.74	703	18
3134	200-35-F	60	0.8	2.3	14.1	82.7	14581	7.71	699	22
3115	200-35-F	120	1.6	1.6	14.3	82.5	14442	5.56	725	32
3122	280-30-F	60	1.5	2.8	13.4	82.3	14266	9.58	712	40
3142	360-25-F	30	1.6	1.2	13.6	83.6	14581	4.46	-	32
3128	320-25-F	60	2.2	0.6	14.6	82.6	14581	2.15	718	24
3116	240-35-F	90	3.6	0.5	13.6	82.3	14266	1.99	711	32
3143	360-25-F	30	0.3	4.4	13.2	82.1	14541	18.13	-	28
3114	160-45-F	90	1.3	2.9	13.5	82.3	14442	10.75	736	40
3127	320-30-F	60	1.1	2.8	13.1	83.0	14581	9.37	743	40
3133	160-50-F	60	0.9	3.3	13.4	82.3	14581	10.47	722	32
3125	280-35-F	60	5.0	0.4	12.0	82.6	14266	1.80	728	22
3124	200-45-F	90	1.2	1.8	14.4	82.6	14266	6.19	734	46
3109	240-45-F	60	1.1	3.3	12.8	82.8	14442	1.39	730	42
3139	240-45-F	60	0.7	3.3	13.9	82.1	14581	10.47	748	36

SHEET No. P-1059

Table VI.
SMOKEBOX GASES.
In this table the tests are arranged according to the increase in evaporation. There is a gradual increase in carbon monoxide or unburned carbon as the rate of firing increases.

58. The relation between the smoke, the carbon monoxide and the amount of dry coal fired per hour in pounds per square foot of grate is shown in Fig. 11. Although the points in each instance are scattered, it is seen that the percentage of smoke increased directly and rapidly with the increase in the rate of combustion, while the increase in the percentage of carbon monoxide is gradual, especially at the lower rates of combustion. This locomotive was hand-fired. No observations were taken of the spark losses.

STACK AND NOZZLE.

59. When commencing this series of tests, locomotive No. 318 was equipped with a circular nozzle, having a diameter of 5.69 inches and an area of 25.4 square inches. Later a rectangular nozzle was substituted, as shown in Fig. 7. Its dimensions were $4\frac{5}{16}$ x $5\frac{7}{8}$ inches and the area was 25.4 square inches or the same as that of the circular nozzle.

60. The stack was 16 inches in diameter at the bottom and tapered toward the top to a diameter of $18\frac{3}{4}$ inches.

61. The maximum evaporation obtained with the circular nozzle was 25,648 pounds of water per hour, at which rate the draft in front of the diaphragm was 6.8 inches of water. The area of the nozzle was then reduced to 23.76 square inches. Thereupon, the evaporation rate dropped to 23,784 pounds of water per hour with a draft in front of diaphragm amounting to 5.8 inches of water.

62. Then the rectangular nozzle was used and the maximum evaporation rate obtained with it was 34,737 pounds of water per hour with a maximum draft in front of the diaphragm of 13.7 inches of water.

63. In order to ascertain the velocity head or pressure across the stack area, so as to draw some comparison between the uniformity of pressure produced by the two kinds of nozzles, readings were taken across the area of the stack at the top. These readings were in inches of mercury from a manometer attached by tubing to a pipe capped at the end, and having an opening one-eighth of an inch in diameter. This was moved across the stack opening at regular intervals and the resulting pressures observed.

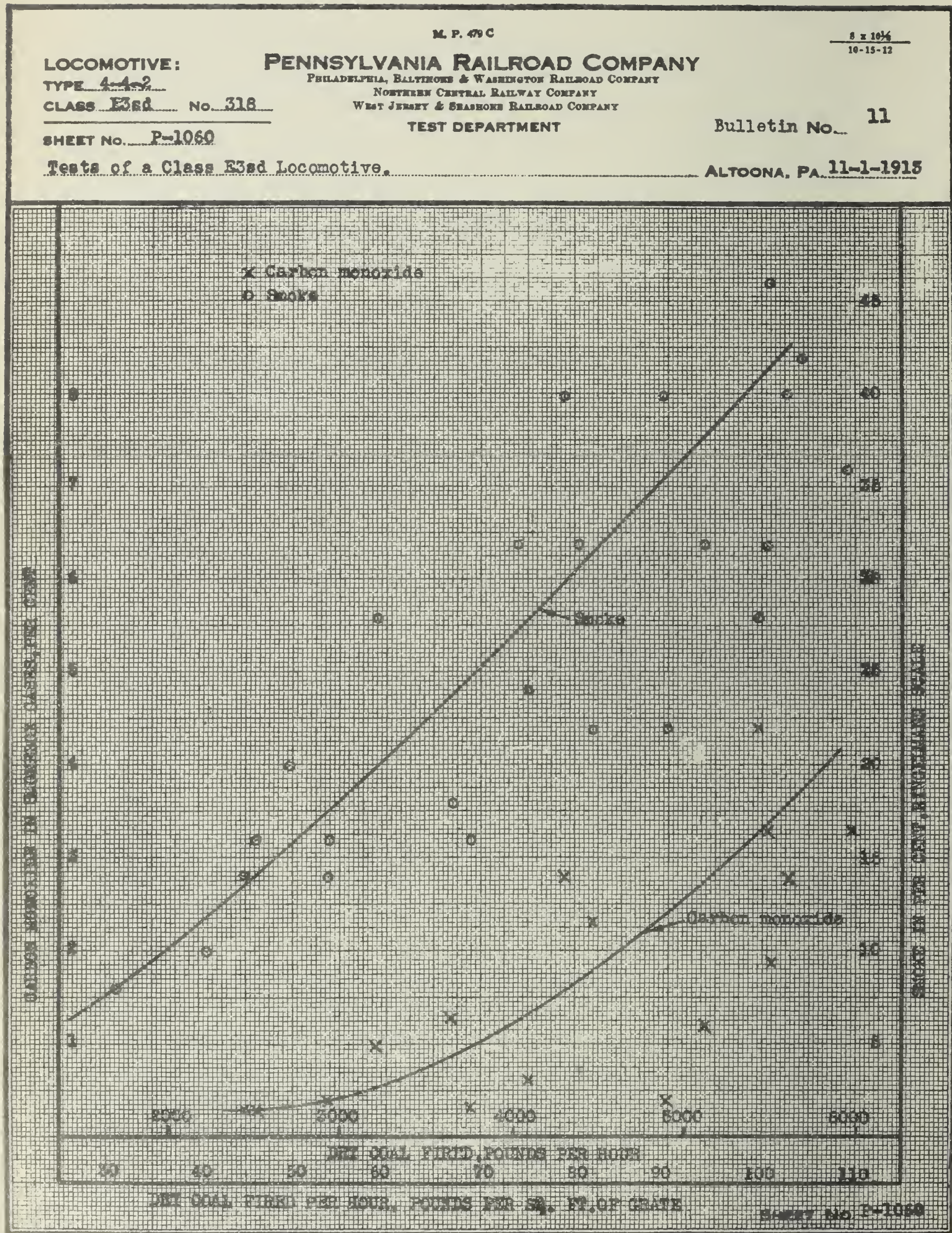

Fig. 11.

CARBON MONOXIDE AND SMOKE.

The carbon monoxide increases in a fairly regular manner with the increase in rate of firing.

64. Fig. 12 shows the readings obtained from the circular nozzle, plotted from left to right and from front to rear across the stack opening for evaporation rates from 15,022 to 25,648 pounds of water per hour. It is seen that as the evaporation rates increase, the curves tend toward a peak showing a high pressure of discharge through the center of the stack.

65. The pressures at the front and rear edges of the stack vary from 0.0 to 0.7 inches. The pressures at the front edge of stack are much higher than those at the rear edge. The pressures at the right and left edges range from 0.1 to 0.6 inches.

66. Similarly the pressures are plotted for the rectangular nozzle in Fig. 13. Here the pressures at the front and rear edges of the stack vary from 0.0 to 1.6 inches, while at the right and left edges the pressures range from 0.1 to 0.6 inches.

67. It is observed that the pressures appear to be more uniform across the stack from front to rear for the rectangular nozzle. From the right to left edges of stack the graphical representation of the pressures shows that when the boiler was evaporating 34,737 pounds of water per hour, the efficiency of the rectangular nozzle had reached its approximate limit. Below this evaporation the pressures across the stack are fairly uniform.

Evaporative Performance.

68. The evaporative performance (Table VII, column 340), shows a range of evaporation of 15,188 to 34,737 pounds of water per hour, or the maximum rate. The equivalent evaporation per hour (column 344) increased from 19,603 pounds to 46,078 pounds per hour.

69. As the equivalent evaporation increased, there was, as shown in Fig. 14, a gradual increase in the branch pipe and superheater temperatures. The boiler temperature shows very little variation, while the boiler, return bend and branch pipe pressures after a slight increase, gradually fell off as the evaporation rate increased.

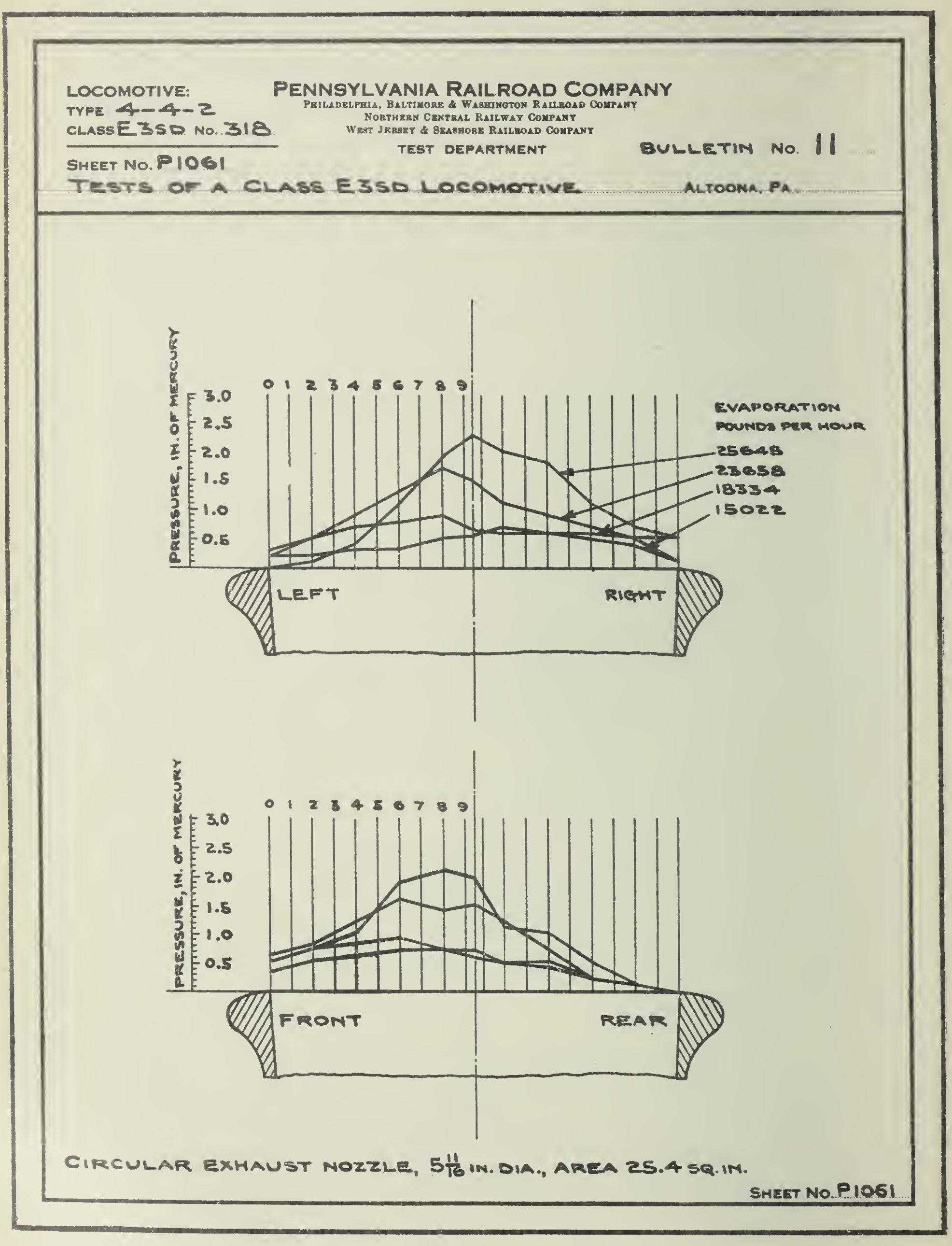

Fig. 12.

STACK PRESSURES.

This figure shows the dynamic pressures across the top of the stack when using a circular nozzle having an area of 25.4 square inches. The maximum evaporation attained was 25,600 pounds per hour.

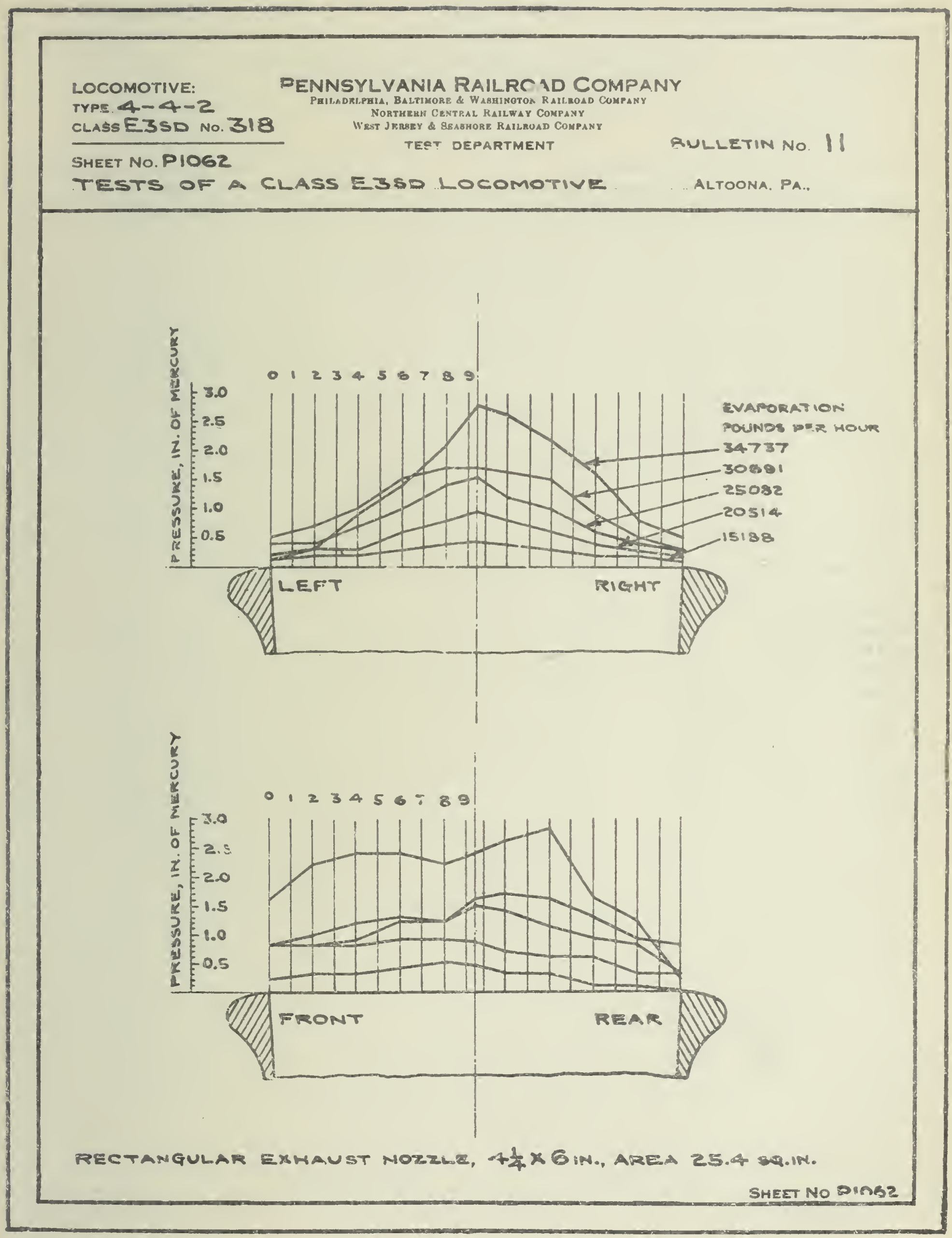

Fig. 13.

STACK PRESSURES.

These results were obtained with a rectangular exhaust nozzle (see Fig. 7) having an area of 25.4 square inches, or the same as the circular nozzle. The evaporation attained in this case was 34,700 pounds per hour, an increase of 26.2 per cent.

M. P. 479—A

8 x 10½
351 4-29-12

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TEST DEPARTMENT

Bulletin No. 11

SHEET No. P-1063

Tests of a Class E3sd Locomotive. ALTOONA, PA. 11-1-1913

EVAPORATIVE PERFORMANCE

Test No.	Test Designation	Duration of Test Mins	Water and Steam: Total Pounds of Water Evap.	Water and Steam: Pounds of Water Evap. Per Hour	Evaporative Performance: Total Water Divided by Total Coal	Evaporative Performance: Equiv. Evap. Per Pound of Dry Coal	Superheat in Branch Pipe Degrees Fahr.	Equiv. Evap. lb. Per Hour	Efficiency of Boiler
			264	340		347	230	344	350
3111	120-20-F	120	30376	15188	8.75	11.49	118.15	19603	77.20
3112	120-30-F	120	36170	18085	7.94	10.51	138.37	23532	70.62
3136	200-20-F	120	38631	19316	7.73	10.48	195.44	25702	69.75
3121	160-30-F	120	41027	20514	7.98	10.82	199.39	27349	73.60
3117	240-20-F	120	42087	21044	7.59	10.34	208.44	28174	70.33
3137	120-40-F	120	42739	21370	7.12	9.65	192.56	28396	64.22
3119	280-20-F	90	34743	23162	7.07	9.68	221.08	31168	65.85
3113	160-35-F	120	47571	23786	7.93	10.59	161.69	31236	71.16
3126	320-20-F	60	25082	25082	6.53	8.88	207.43	33539	60.40
3135	200-35-F	60	25650	25650	6.87	9.42	227.37	34513	62.69
3134	200-35-F	60	26232	26232	5.75	7.86	218.04	35196	52.31
3115	200-35-F	120	53847	26924	6.55	8.82	179.26	35641	59.26
3122	280-30-F	60	26629	26629	6.07	8.31	227.38	35837	56.53
3142	360-25-F	30	13984	27968	5.34	7.31	220.83	37549	48.65
3128	320-25-F	60	28079	28079	6.70	9.18	221.40	37711	61.10
3116	240-35-F	90	43417	28945	6.47	8.82	213.96	38760	60.00
3143	360-25-F	30	14704	29408	5.31	7.25	221.47	39463	48.38
3114	160-45-F	90	44927	29951	6.02	8.09	175.07	39566	54.35
3127	320-30-F	60	29743	29743	5.19	7.12	228.29	39964	47.39
3133	160-50-F	60	30691	30691	5.47	7.47	211.67	41080	49.71
3125	280-35-F	60	31638	31638	6.33	8.65	226.80	42502	58.84
3124	200-45-F	90	49327	32885	5.89	8.07	232.32	44285	54.89
3109	240-45-F	60	34737	34737	5.99	8.08	193.44	46073	54.29
3139	240-45-F	60	33970	33970	5.57	7.71	253.84	46078	51.31

SHEET No. P-1063

Table VII.

EVAPORATIVE PERFORMANCE.

The evaporation ranged from 15,000 to 34,000 pounds per hour, while the efficiency of the boiler ranged from 77 per cent. to 47 per cent.

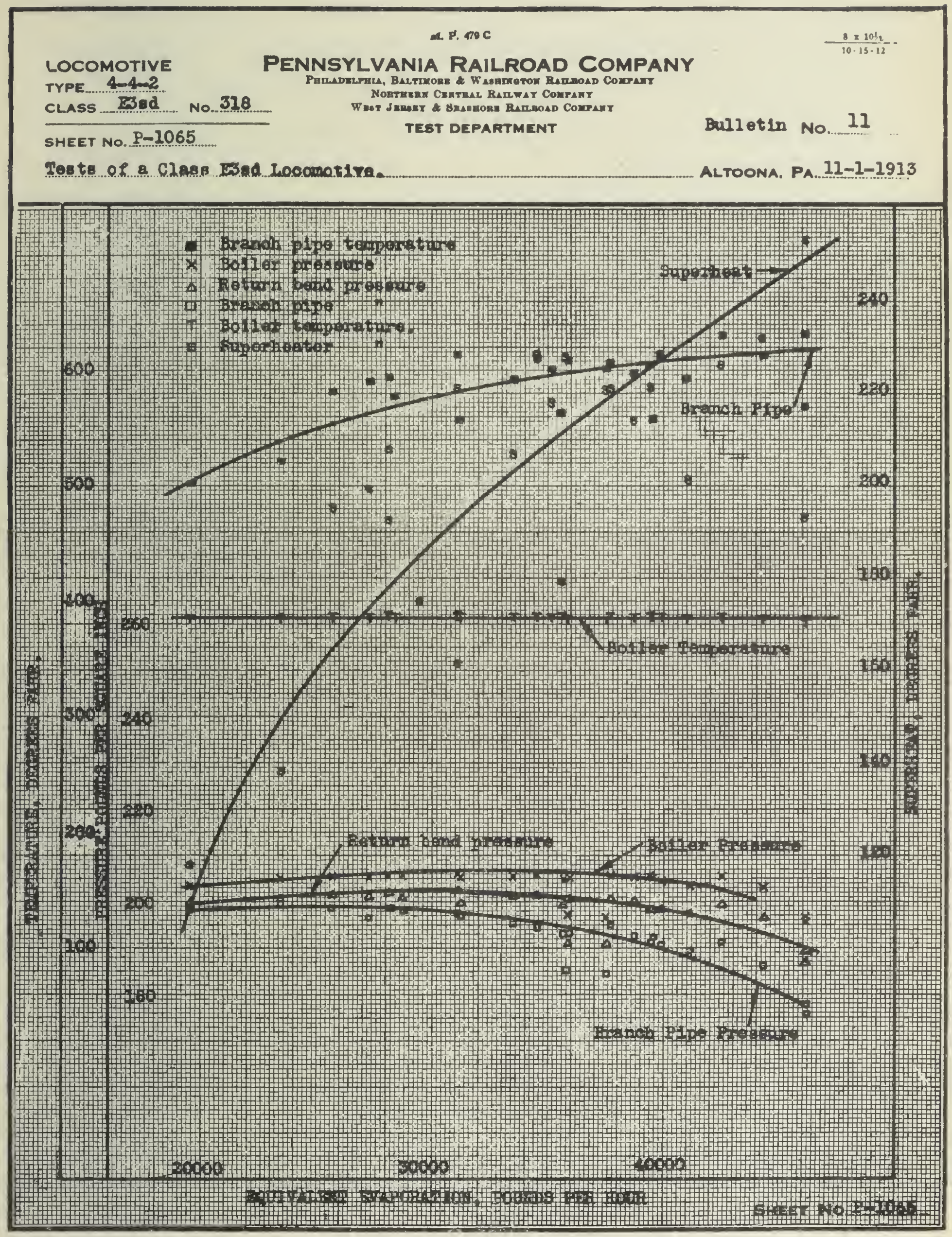

Fig. 14.

STEAM TEMPERATURE, PRESSURE AND SUPERHEAT.

The curves at the lower part of the figure show the drop in pressure between the boiler and steam chest.

70. The increase in the equivalent evaporation in pounds per hour per square foot of heating surface with the increase in the draft, is shown in Fig. 15. As the draft in the front of diaphragm increased from 3.3 to 12.8 inches of water, the equivalent evaporation per hour per square foot of heating surface increased from 8.23 to 19.35 pounds.

71. The evaporative performance of the boilers is shown graphically in Fig. 16. There was a rapid increase in the water evaporated with a regular increase in the dry coal fired per hour. The evaporative performance for the E2d saturated steam boiler is higher than that of the E3sd superheater boiler by about 11 per cent., on account of the larger water heating surface in the saturated steam boiler.

72. The equivalent evaporation per pound of dry coal decreased with the increase in the rate of combustion measured in pounds of coal per square foot of grate. This is shown in Fig. 17. The results plot in a straight line expressed by the equation $E = 13.2 - (0.057)\ C$, when "C" represents the pounds of dry coal fired per hour per square foot of grate area.

73. In Fig. 18 the equivalent evaporation is plotted as ordinates with the equivalent evaporation per square foot of heating surface as abscissae. The equivalent evaporation per pound of dry coal (Table VII, column 347) ranged from 11.49 to 7.12 pounds—the minimum, while the equivalent evaporation per square foot of heating surface varied from 8.23 pounds to a maximum of 19.35 pounds.

74. It is seen, Fig. 18, that when the E3sd boiler was forced to an equivalent evaporation of 16 pounds per square foot of heating surface, there was evaporated 8.4 pounds of water per pound of dry coal. Comparing this with the performance of the E6s locomotive, the curve for which is also shown in Fig. 18, at the same rate of evaporation, there were 7.7 pounds of water evaporated per pound of dry coal. In the case of the E6 saturated steam locomotive 8.7 pounds of water per pound of dry coal were evaporated. If the E6 locomotive could be forced to the maximum rate or approximately 20 pounds per hour per square foot of heating surface, similar to the E3sd locomotive, its water rate per pound of coal would be 2 pounds lower at that equivalent evaporation

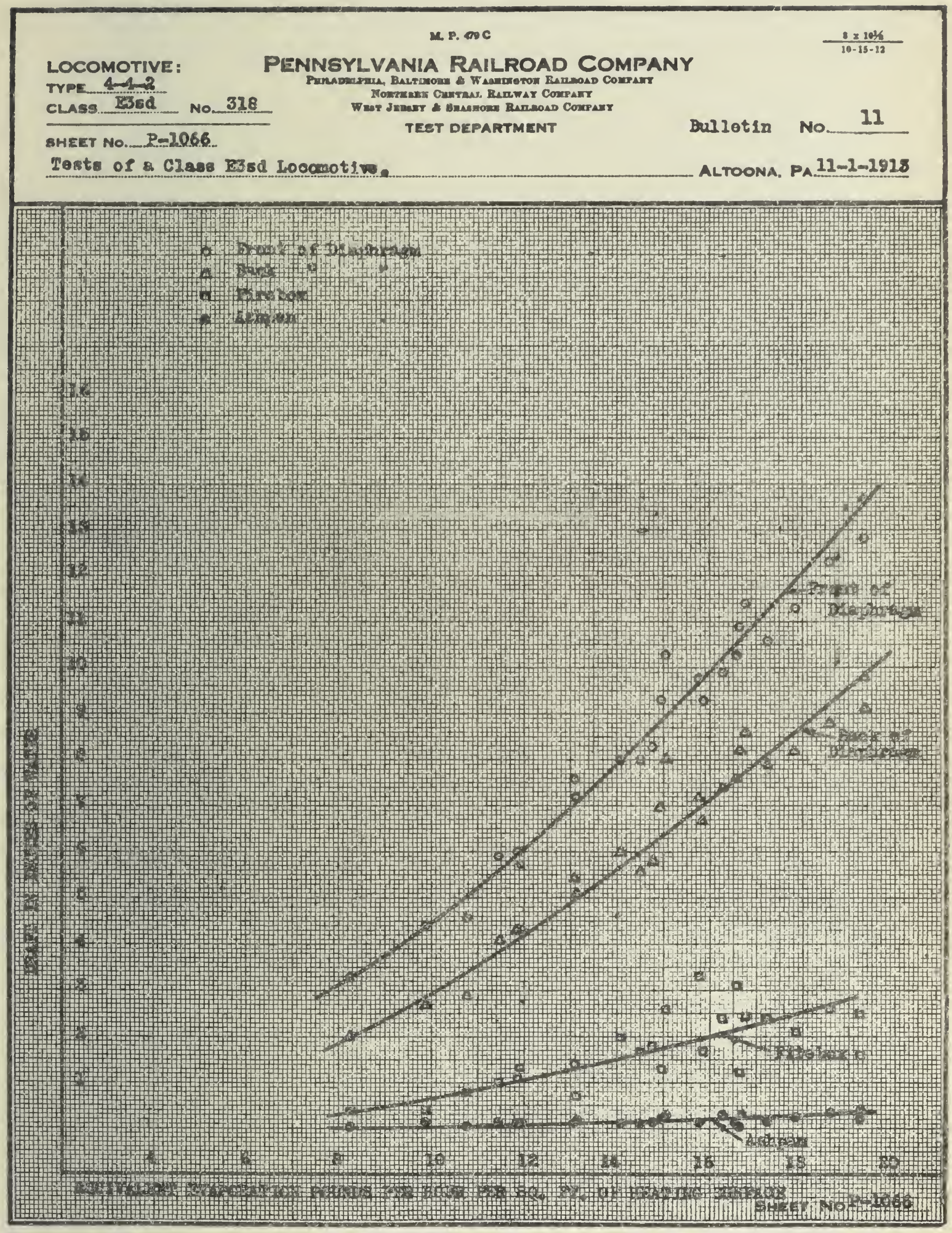

Fig. 15.

DRAFT AND EVAPORATION.

This figure corresponds with Fig. 10, except that the lower scale is in evaporation per square foot of heating surface.

per square foot of heating surface. These are all Atlantic type locomotives burning Penn Gas Coal, and tested under practically the same conditions.

75. The comparison, thus presented in Fig. 18 shows a very creditable evaporative performance for the E3sd locomotive when compared with other locomotives of the same type.

Evaporation Rate, Boiler and Superheater.

76. Table VIII is presented to show the work done by the superheater as compared with that of the boiler. These results are calculated and arranged in order according to the total evaporation rate as given in column 344.

77. The Table, besides including the test number and test designation, shows the water evaporated in pounds per hour, the equivalent evaporation from and at 212 degrees Fahr., in pounds per hour for the boiler, for the superheater, and the boiler and superheater.

78. In the last column is given the ratio of equivalent evaporation per square foot of heating surface in the superheater to that in the boiler.

79. An average of the last column in this table shows that 30.4 per cent. of the equivalent evaporation per square foot of heating surface takes place in the superheater.

80. For the E6s locomotive it was found (see Bulletin 21, Par. 45), that the rate of heat transfer per unit of superheater surface amounted to 32 per cent. of that of the boiler surface, or but 1.6 per cent. more than that obtained in the E3sd locomotive.

81. The superheating surface in the E6s locomotive is 22 per cent. of the total heating surface, while in the case of the E3sd locomotive the proportion is 24 per cent.

82. The E2d and E3sd locomotive boilers are alike except that the latter is equipped with a Schmidt superheater and arch. The efficiency of the E2d boiler is greater than the E3sd superheater boiler (Fig. 21), when the equivalent evaporation exceeded

M. P. 479—A

8 x 10½
351 4-29-12

LOCOMOTIVE:
TYPE 4-4-2
CLASS E3sd NO. 318

SHEET NO. P1064

Tests of a Class E3sd Locomotive.

PENNSYLVANIA RAILROAD COMPANY
PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY
TEST DEPARTMENT

Bulletin No. 11

ALTOONA, PA. 11-1-1913

EVAPORATION RATE,BOILER AND SUPERHEATER

Test No.	Test Designation	Water Evaporated Lb.per Hour	Equiv. Evap. From and at 212°F per Hour: Boiler Excluding Super-header	Superheater Alone	Boiler Including Superheater	Per sq.ft. of heating surface: Boiler Excluding Superheater	Superheater Alone	Boiler Including Superheater	Ratio of equiv. Evap.per sq.ft. of heating surface in superheater to that in Boiler
		340			344			345	
3111	120-20-F	15188	18516	1087	19603	9.97	1.94	8.23	0.195
3112	120-30-F	18085	22047	1485	23532	12.10	2.65	9.88	0.219
3136	200-20-F	19316	23582	2120	25702	12.95	3.78	10.79	0.292
3121	160-30-F	20514	25047	2302	27349	13.76	4.11	11.48	0.299
3117	240-20-F	21044	25708	2466	28174	14.12	4.39	11.83	0.311
3137	120-40-F	21370	26090	2306	28396	14.33	4.11	11.92	0.287
3119	280-20-F	23162	28266	2902	31168	15.52	5.18	13.09	0.334
3113	160-35-F	23786	29049	2187	31236	15.95	3.90	13.12	0.245
3126	320-20-F	25082	30612	2927	33539	16.81	5.22	14.08	0.311
3135	200-35-F	25650	31309	3204	34513	17.19	5.72	14.49	0.333
3134	200-35-F	26232	31989	3207	35196	17.57	5.72	14.78	0.326
3115	200-35-F	26924	32889	2752	35641	18.06	4.91	14.97	0.272
3122	280-30-F	26629	32492	3345	35837	17.84	5.97	15.05	0.335
3142	360-25-F	27968	34122	3427	37549	18.74	6.11	15.77	0.326
3128	320-25-F	28079	34224	3487	37711	18.79	6.22	15.83	0.331
3116	240-35-F	28945	35287	3473	38760	19.38	6.19	16.28	0.319
3143	360-25-F	29408	35885	3578	39463	19.71	6.38	16.57	0.324
3114	160-45-F	29951	36581	2985	39566	20.09	5.32	16.61	0.265
3127	320-30-F	29743	36222	3742	39964	19.89	6.67	16.78	0.335
3133	160-50-F	30691	37453	3627	41080	20.57	6.47	17.25	0.315
3125	280-35-F	31636	38570	3932	42502	21.18	7.01	17.85	0.331
3124	200-45-F	32885	40083	4192	44275	22.01	7.48	18.60	0.340
3109	240-45-F	34737	42328	3745	46073	23.25	6.68	19.35	0.287
3139	240-45-F	33970	41432	4646	46078	22.75	8.29	19.35	0.364

SHEET NO. P-1064

Table VIII.

EVAPORATION RATE, BOILER AND SUPERHEATER.

This table shows the proportion of the heat absorbed by the water heating and superheating surfaces of the boiler. According to the last column, per square foot of heating surface, the superheater absorbed about 30 per cent. of the heat absorbed by the water heating surface.

500 pounds per square foot of grate per hour. However, at no rate of evaporation is the average efficiency of the saturated steam boiler greater by more than 2 per cent. than for the superheated steam boiler as shown on this diagram.

83. This small loss in efficiency is compensated for many times by the saving in the amount of heat supplied to the engines per i.h.p. hour for the superheater locomotive when performing the same work at like speeds. This was shown clearly in the case of the E6s locomotive (Bulletin 21, Par. 109), which states the saving in heat expenditure for the E6s locomotive over the E6 saturated locomotive was 24.16 per cent. At the same time, the saving in coal for the E6s locomotive amounted to 24.4 per cent. per indicated horse-power hour above that for the E6 saturated steam locomotive.

84. Unfortunately owing to the limited number of tests made with the E2d locomotive we have not sufficient data at hand to make a fair comparison between the E2d saturated steam and E3sd superheater locomotives.

85. Fig. 17 showing the equivalent evaporation per pound of dry coal at the different rates of firing for the E2d saturated steam and E3sd superheater boilers illustrates the better performance of the saturated steam or E2d locomotive boiler, when the rate of firing exceeds 45 pounds of coal per hour per square foot of grate. This is due to the greater evaporation rate obtained from the saturated steam locomotive.

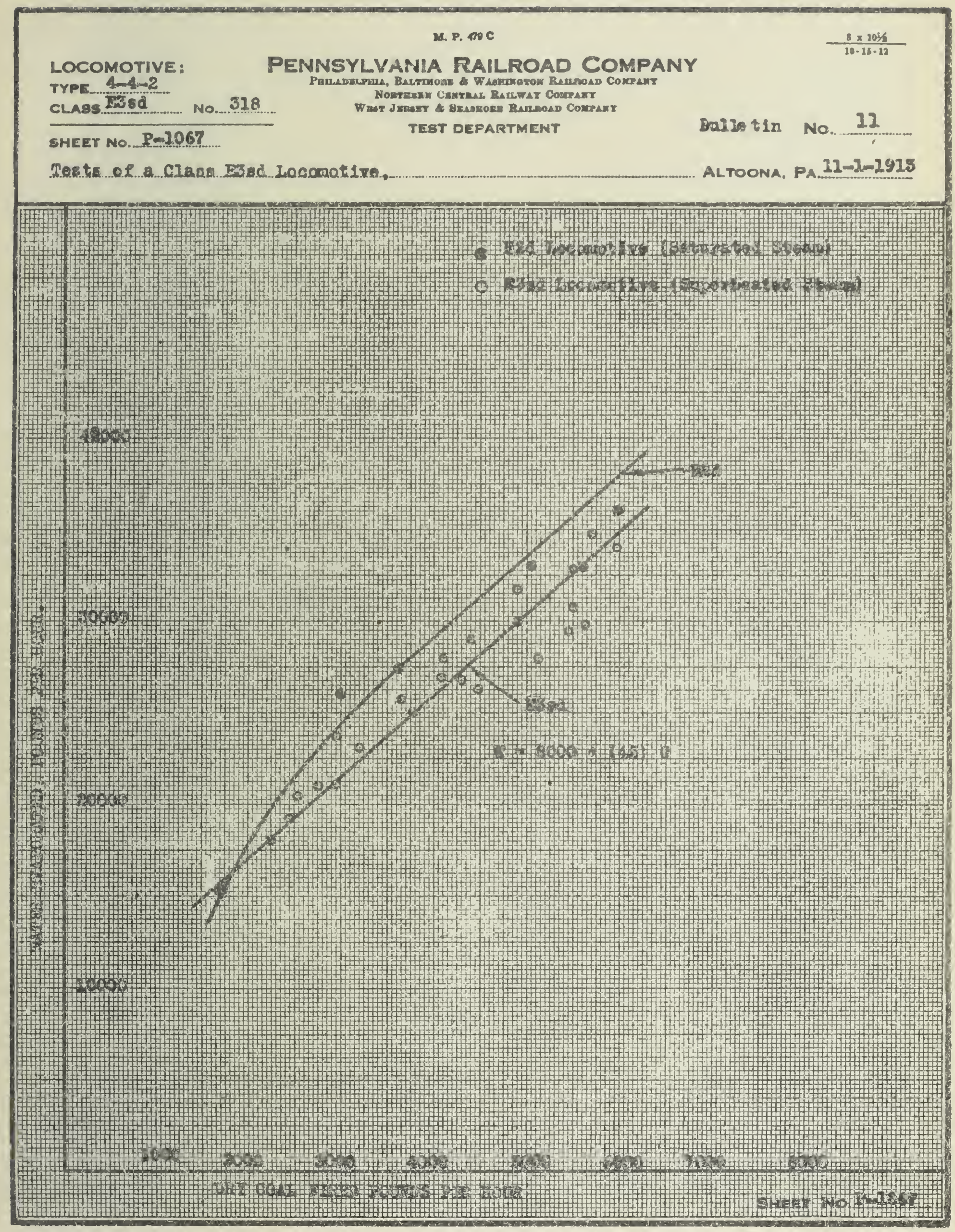

Fig. 16.

COAL FIRED AND WATER EVAPORATED.

On this diagram a curve for the E2d saturated steam locomotive is shown. Without the superheater the evaporation per pound of coal is slightly improved.

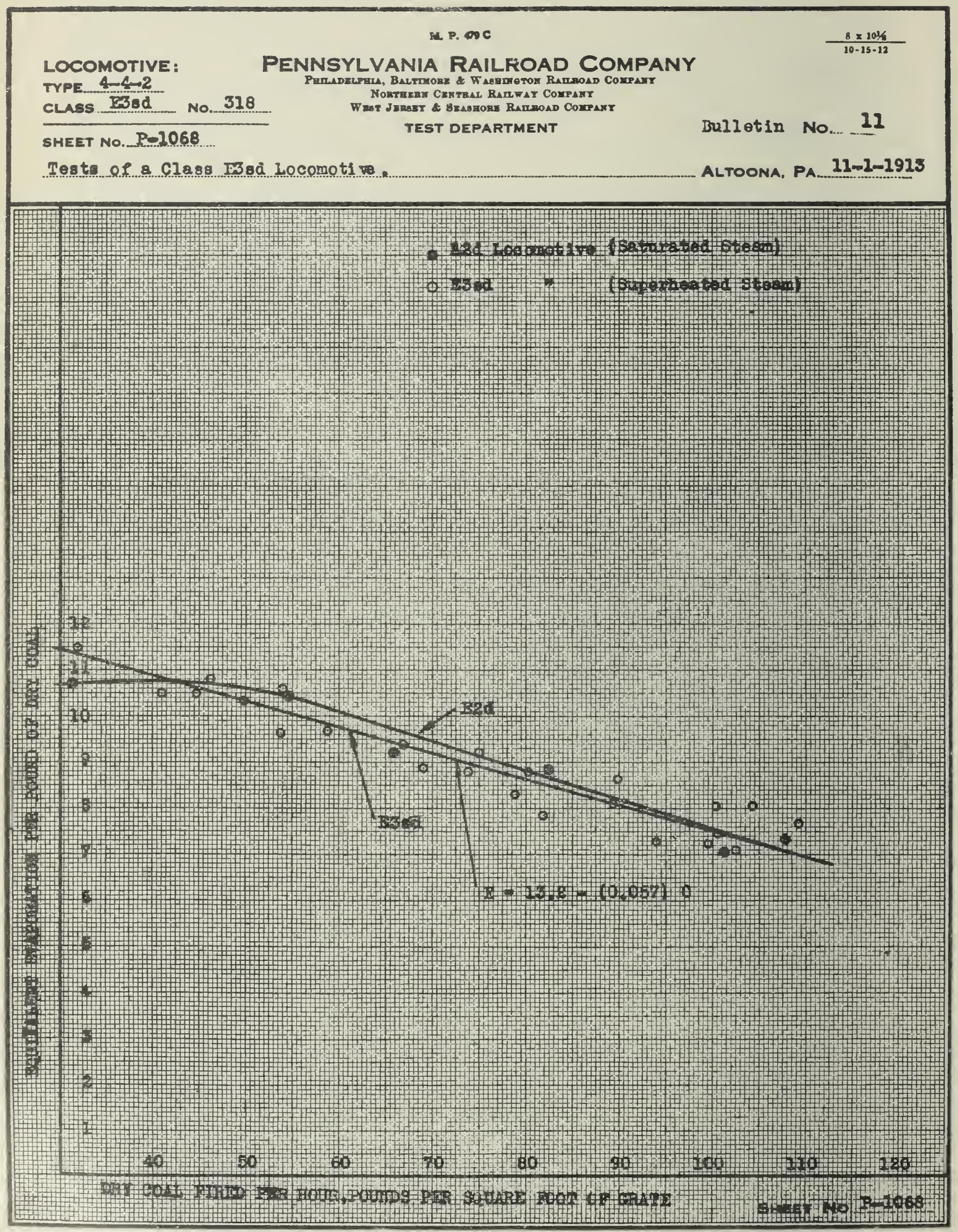

Fig. 17.

DRY COAL FIRED AND EQUIVALENT EVAPORATION PER POUND OF DRY COAL.

The E2d, saturated steam locomotive, shows a slight advantage over the E3sd, superheater locomotive, between rates of firing of 43 and 110 pounds of dry coal, due to the greater evaporating surface of the saturated steam boiler.

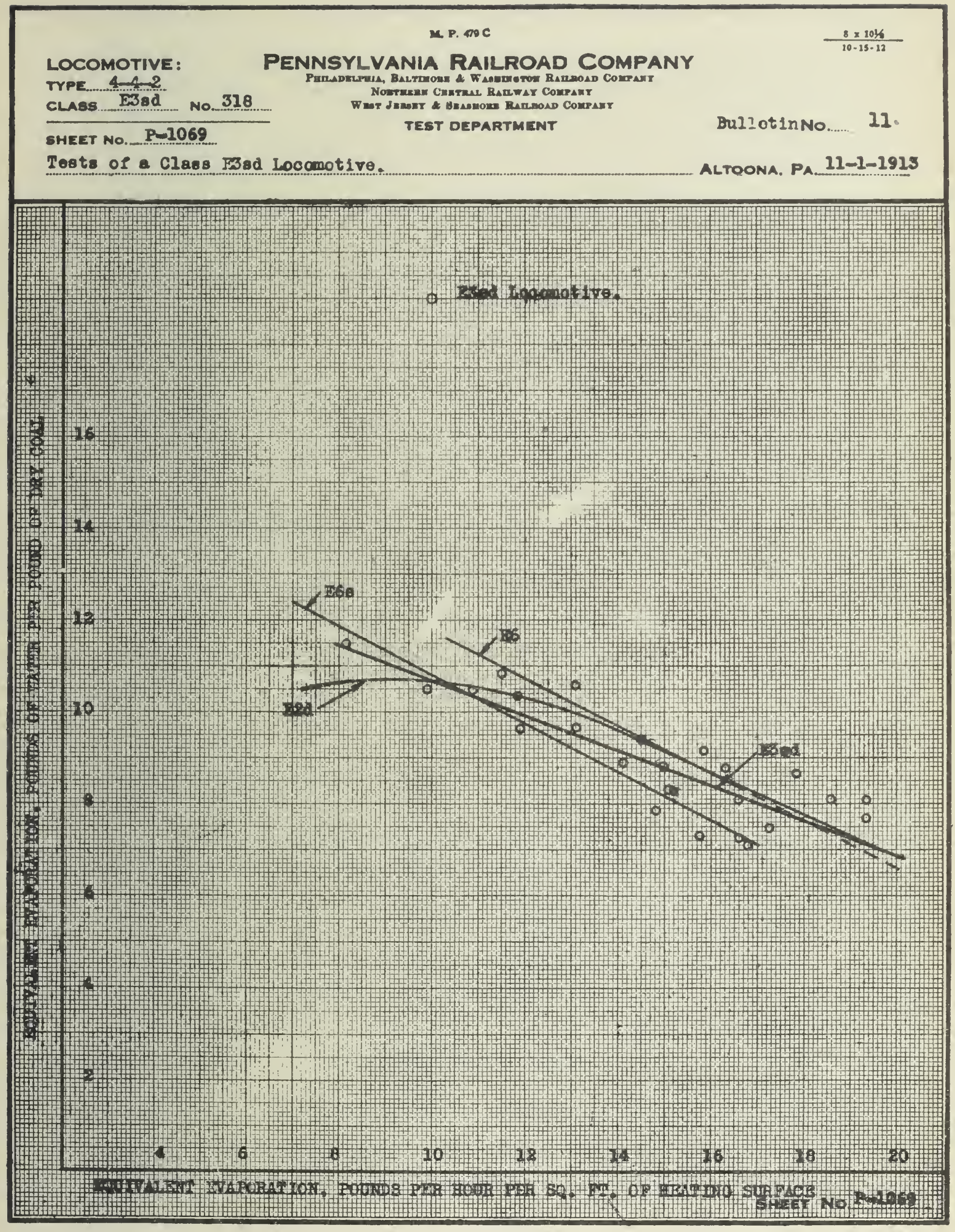

Fig. 18.

EQUIVALENT EVAPORATION PER POUND OF COAL AND RATE OF EVAPORATION.

This diagram shows curves for four locomotives. The E6 and E6s have larger boilers than the E2d and E3sd.

Boiler Power and Efficiency.

86. The boiler horse-power obtained from locomotive No. 318 during the tests is shown in Table IX, column 349. There is also given in this table, the boiler horse-power per square foot of heating surface, per square foot of grate surface, and the boiler efficiency.

87. The total boiler horse-power ranged from a minimum of 568 horse-power to a maximum of 1336 horse-power at the maximum evaporation rate. This maximum is equivalent to 0.56 boiler horse-power per square foot of heating surface or 24.4 horse-power per square foot of grate surface.

88. The range of boiler efficiency (column 350, Table IX) was between 77.2 and 51.3 per cent.

89. Fig. 19 shows graphically the decrease in the boiler efficiency with the increase in the evaporation rate. Likewise it is shown in Fig. 20 that the boiler efficiency decreased with the increase in the rate of combustion.

90. The comparison of the boiler efficiencies (Fig. 21) of the superheated steam locomotive and the saturated steam locomotive is made under practically the same conditions, using the same fuel. It is shown that the saturated steam locomotive has a little greater boiler efficiency due to its greater water heating surface.

Steam Passages.

91. The areas of the steam passages in square inches from the boiler to the exhaust nozzle at restricted points are shown graphically in Fig. 22. The areas are shown by solid black lines. The corresponding pressures in pounds (gage) are shown by the open spaces, while the velocities are indicated in feet per minute by the cross-hatched spaces.

92. This Fig. 22 is interesting for it clearly presents the action of the steam in its passage from boiler to stack. The superheater offers a considerable resistance to the flow of the steam and the resultant effect on its velocity and pressure caused by this restriction may be seen.

93. The average boiler pressure at this time was 196 pounds. The duration of the test was one hour. The pressure at the superheater return bend or at the center of its length was 187 pounds.

M. P. 479—A

8 x 10½
851 4-29-12

LOCOMOTIVE:
TYPE 4-4-2
CLASS E3sd No. 318

PENNSYLVANIA RAILROAD COMPANY
PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY
TEST DEPARTMENT

Bulletin No. 11

SHEET No. P-1070
Tests of a Class E3sd Locomotive.
ALTOONA, PA. 11-1-1913

BOILER POWER

Test No.	Test Designation	Duration of Test Mins.	Equiv. Evap. Pounds Per sq.ft. of Grate Surface Per Hour	Equiv. Evap. Pounds Per sq.ft. of Heating Surface Per Hour	Boiler Horse Power Total	Boiler Horse Power Per sq.ft. of Heating Surface	Boiler Horse Power Per sq.ft. of Grate Surface	Efficiency of Boiler
				345	349			350
3111	120-20-F	120	357.7	8.23	568.2	0.239	10.39	77.20
3112	120-30-F	120	429.4	9.88	682.1	0.286	12.47	70.62
3136	200-20-F	120	469.0	10.79	745.0	0.312	13.61	69.75
3121	160-30-F	120	499.1	11.48	792.7	0.333	14.49	73.60
3117	240-20-F	120	514.1	11.83	816.6	0.342	14.93	70.33
3137	120-40-F	120	518.2	11.92	823.1	0.346	15.41	64.22
3119	280-20-F	90	568.8	13.09	903.4	0.379	16.52	65.85
3113	160-35-F	120	570.0	13.12	905.4	0.380	16.55	71.16
3126	320-20-F	60	612.0	14.08	971.9	0.408	18.29	60.40
3135	200-35-F	60	629.8	14.49	1000.4	0.420	18.65	62.69
3134	200-35-F	60	642.3	14.78	1020.2	0.428	18.89	52.31
3115	200-35-F	120	650.4	14.97	1033.1	0.434	18.99	59.26
3122	280-30-F	60	654.0	15.05	1038.7	0.436	19.90	56.53
3142	360-25-F	30	685.2	15.77	1088.4	0.457	19.98	48.65
3128	320-25-F	60	688.2	15.83	1093.1	0.459	20.54	61.10
3116	240-35-F	90	707.3	16.28	1123.5	0.472	20.91	60.00
3143	360-25-F	30	720.1	16.57	1143.9	0.480	20.97	48.38
3114	160-45-F	90	722.0	16.61	1146.8	0.483	21.18	54.35
3127	320-30-F	60	729.3	16.78	1158.4	0.486	21.77	47.39
3133	160-50-F	60	749.6	17.25	1190.7	0.499	21.77	49.71
3125	280-35-F	60	775.6	17.85	1231.9	0.517	22.52	58.84
3124	200-45-F	90	807.9	18.60	1283.6	0.539	23.47	54.89
3109	240-45-F	60	842.3	19.35	1335.4	0.561	24.41	54.29
3139	240-45-F	60	842.4	19.35	1335.6	0.561	24.42	51.31

SHEET No. P-1070

Table IX.
BOILER POWER.
Column 345 shows the remarkably high figure of 19.35 pounds of water evaporated per square foot of heating surface per hour.

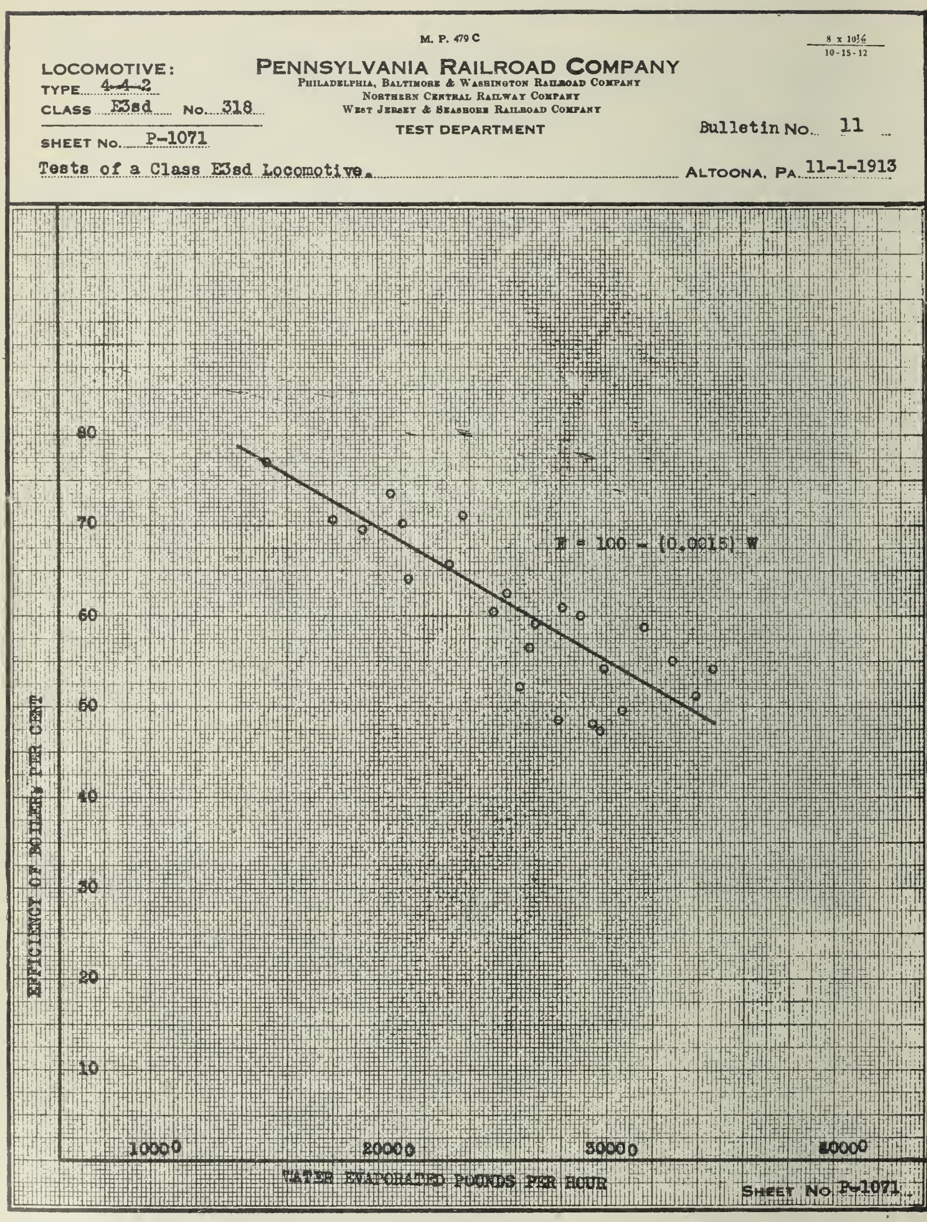

Fig. 19.
EFFICIENCY OF BOILER AND EVAPORATION PER HOUR.

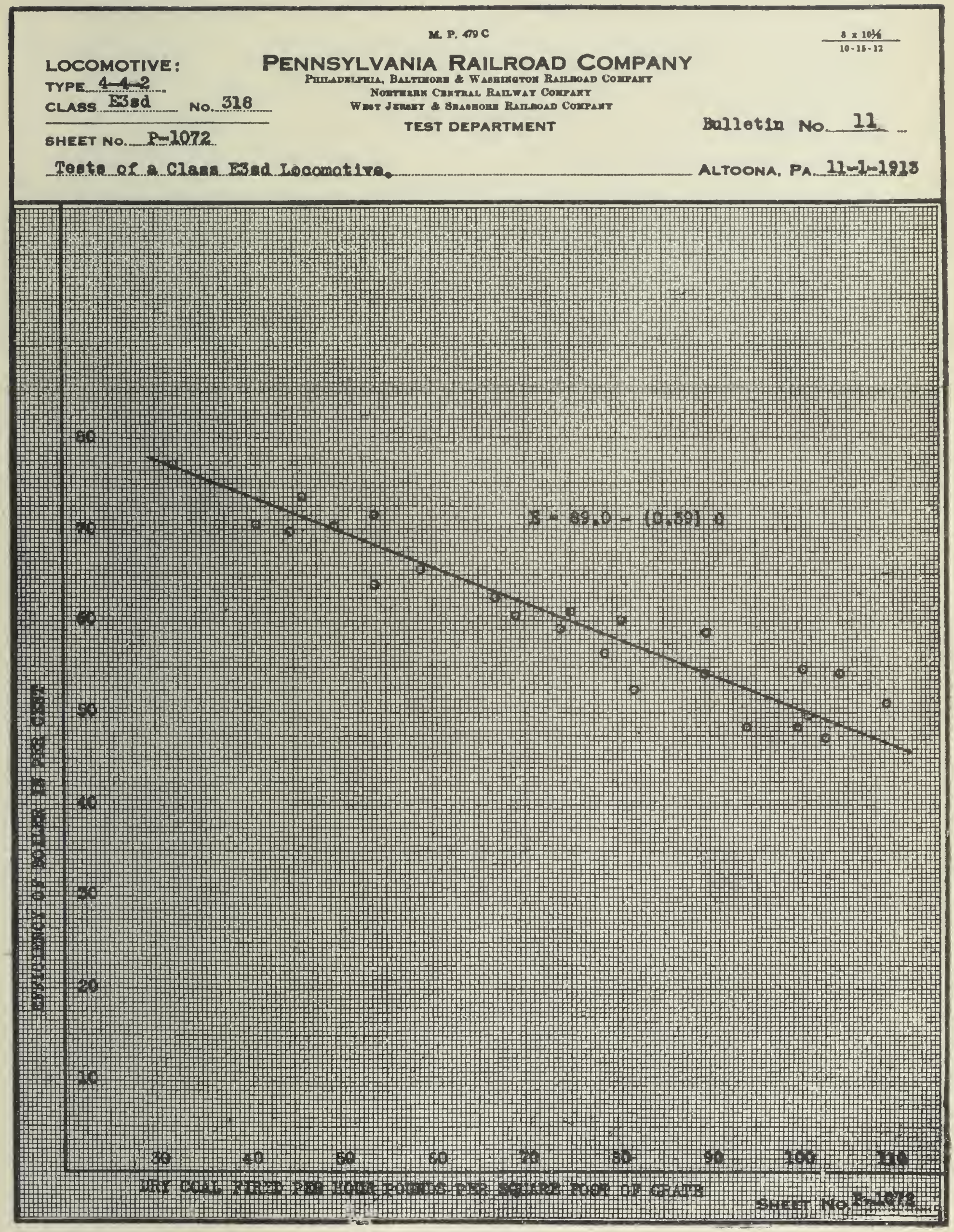

Fig. 20.

EFFICIENCY OF BOILER AND RATE OF COMBUSTION.

Throughout a range of combustion from 30 to 110 pounds per square foot of grate, the efficiency ranges from 77 down to 47 per cent.

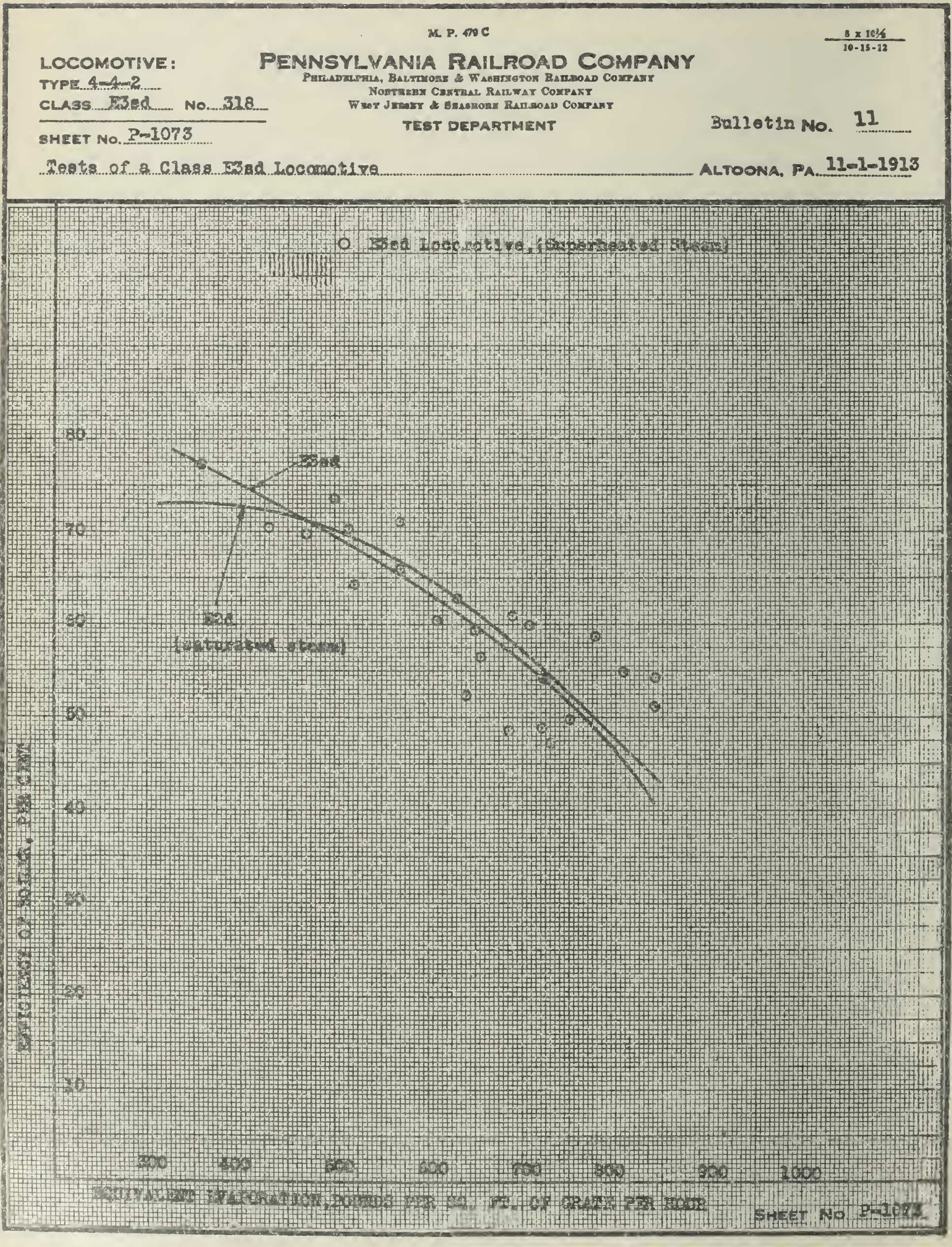

Fig. 21.

EFFICIENCY OF BOILER AND EVAPORATION PER SQUARE FOOT OF GRATE.

The grates of these two boilers are alike; the saturated steam boiler shows a slightly better performance than the superheater boiler.

M. P. 470 C

8 x 10½
10-15-12

LOCOMOTIVE:
TYPE 4-4-2
CLASS E3sd NO. 318

PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

TEST DEPARTMENT

SHEET NO. P-1074

Bulletin No. 11

Tests of a Class E3sd Locomotive. ALTOONA, PA. 11-1-1913

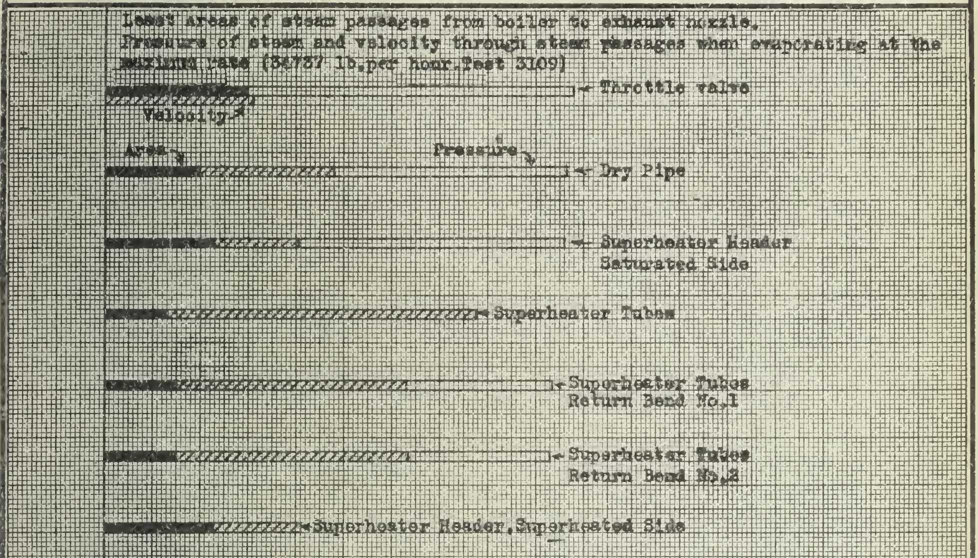

Fig. 22.

AREA OF STEAM PASSAGES.

On this diagram are shown the steam passage areas between the throttle and exhaust nozzle, with the pressure and steam velocity.

The final pressure in the branch pipe was 176 pounds. The total drop in pressure was 20 pounds or approximately 10 per cent. In the case of the E6s locomotive No. 89 with maximum evaporation, the drop was 6 per cent.

Superheat.

94. The range of superheat extended from 118 to 254 degrees Fahr. during the tests. This latter degree of superheat at the maximum rate of evaporation is approximately 8 per cent. greater than obtained from the E6s locomotive No. 89. Namely: 234 degrees Fahr. The amount of heat transferred across the superheating surfaces of the E6s boiler was approximately 82,317 B.t.u. per minute under maximum conditions, while across the superheating surfaces of the E3sd boiler was transferred 80,482 B.t.u. per minute. The amounts of heat transferred across one square foot of superheating surface of the E6s and E3sd boilers were 120 and 143 B.t.u. per minute, respectively, or approximately 19.5 per cent. more for the E3sd. This no doubt accounts for the higher degree of superheat obtained by the E3sd locomotive. The grate areas were approximately the same and the rate of combustion per square foot of grate for the E6s locomotive at the maximum rate of evaporation was 115.52 pounds, while that of the E3sd locomotive was 109.27 and the increased wire drawing apparent from the drop in pressure due either to the length or restricted area through the tubes accounting for the higher possible transfer rate.

95. The ratio of the equivalent evaporation per square foot of heating surface in the superheater to that in the boiler ranged from 0.195 to 0.364, Table VIII. This is somewhat less than that for the E6s locomotive.

Boiler Tube Temperatures.

96. A long thermo-couple was used to take the temperature readings in the superheater flue and the boiler tube. These readings were taken at one foot intervals, the entire length of the flue and tube. (See also Bulletin No. 21, Par. 61.)

97. The temperature readings are shown graphically in Figs. 23 to 28 inclusive, with respect to the length of the flue or tube, which is drawn to scale below the temperature curve.

98. The temperatures obtained indicate that the gases entering the tubes have a lower temperature than the temperature at the center of the firebox as measured by a pyrometer. During these tests for which the temperature curves are plotted, the range of temperature in the firebox was from 1962 to 2322 degrees Fahr. The temperature of the gases entering the tubes varied from 1660 to 2000 degrees Fahr. or about 7 per cent. less.

99. It is further seen that a large part of the heat of the gases was absorbed by the tube before they had passed through half the length of the tube. After the first 6 feet, the drop in temperature in the tubes was more gradual, resulting in a similar slower transfer rate, and at the smokebox end the heat in the gases had fallen to a temperature ranging from 730 to 820 degrees Fahr.

100. Further, it is observed at low rates of combustion ranging from 2452 to 3000 pounds of coal per hour the temperatures in boiler tube and superheater flue were nearly equal, while at higher rates of combustion, the temperature in the boiler was somewhat higher than that in the superheater flue for the first three feet; beyond this point the temperature of the tube drops approximately 90 degrees below that of the superheater flue. An exception to this is shown in Fig. 27, where the superheater flue shows a higher temperature throughout its length than the boiler tube. The rate of combustion during this test was 5616 pounds of coal per hour, the draft was 8.6 inches of water. The difference in temperature in this case was approximately 100 degrees Fahr.

101. In view of the fact that the E3sd and E6s locomotive boiler tubes are of the same diameters and that the E3sd boiler tubes are 15 inches longer than those in the E6s boiler, it may be of interest to ascertain the greater absorbing capacity of the longer tube.

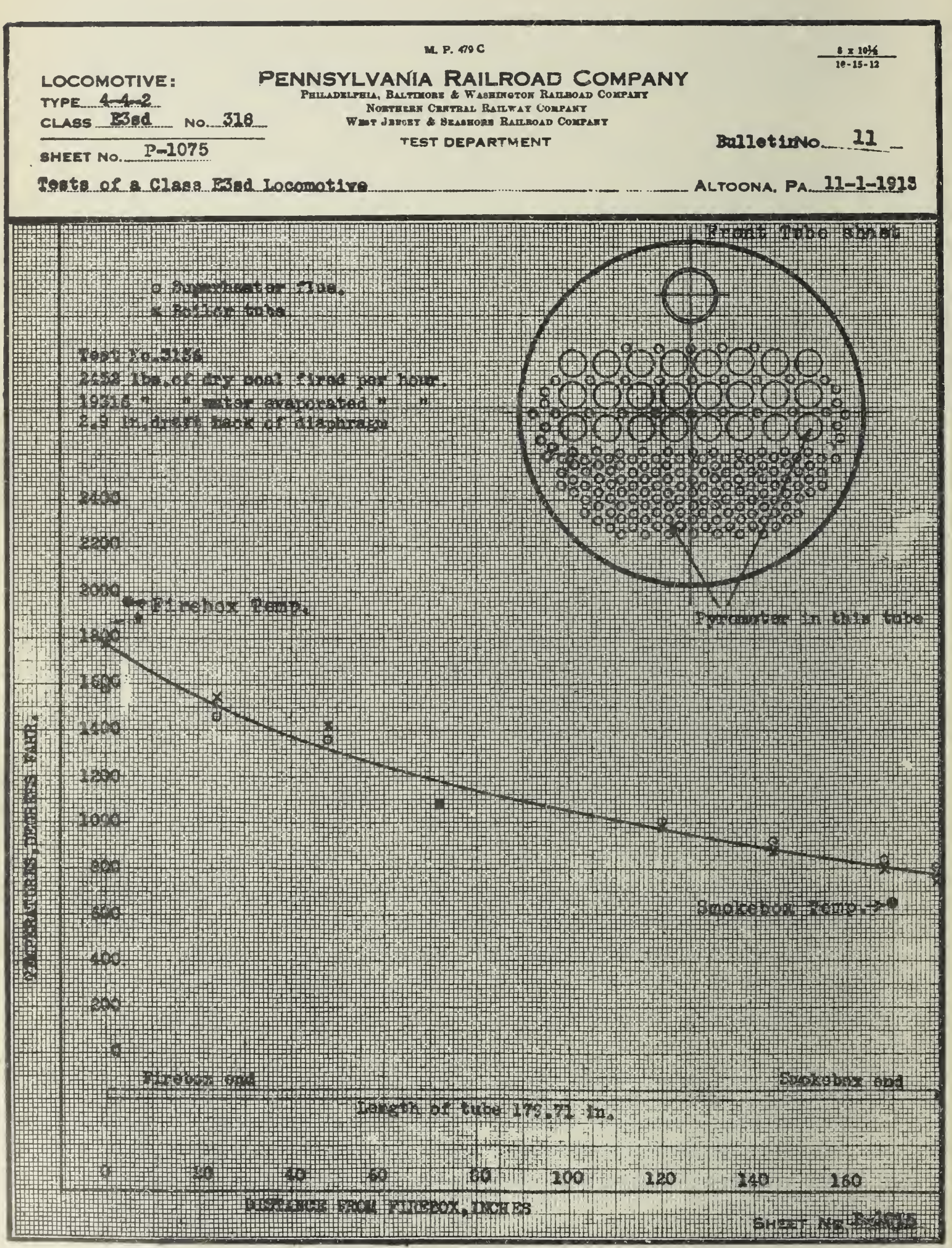

Fig. 23.

TEMPERATURES IN THE SUPERHEATER FLUE AND BOILER TUBE.

Temperatures for a rate of coal burning of 2400 pounds per hour.

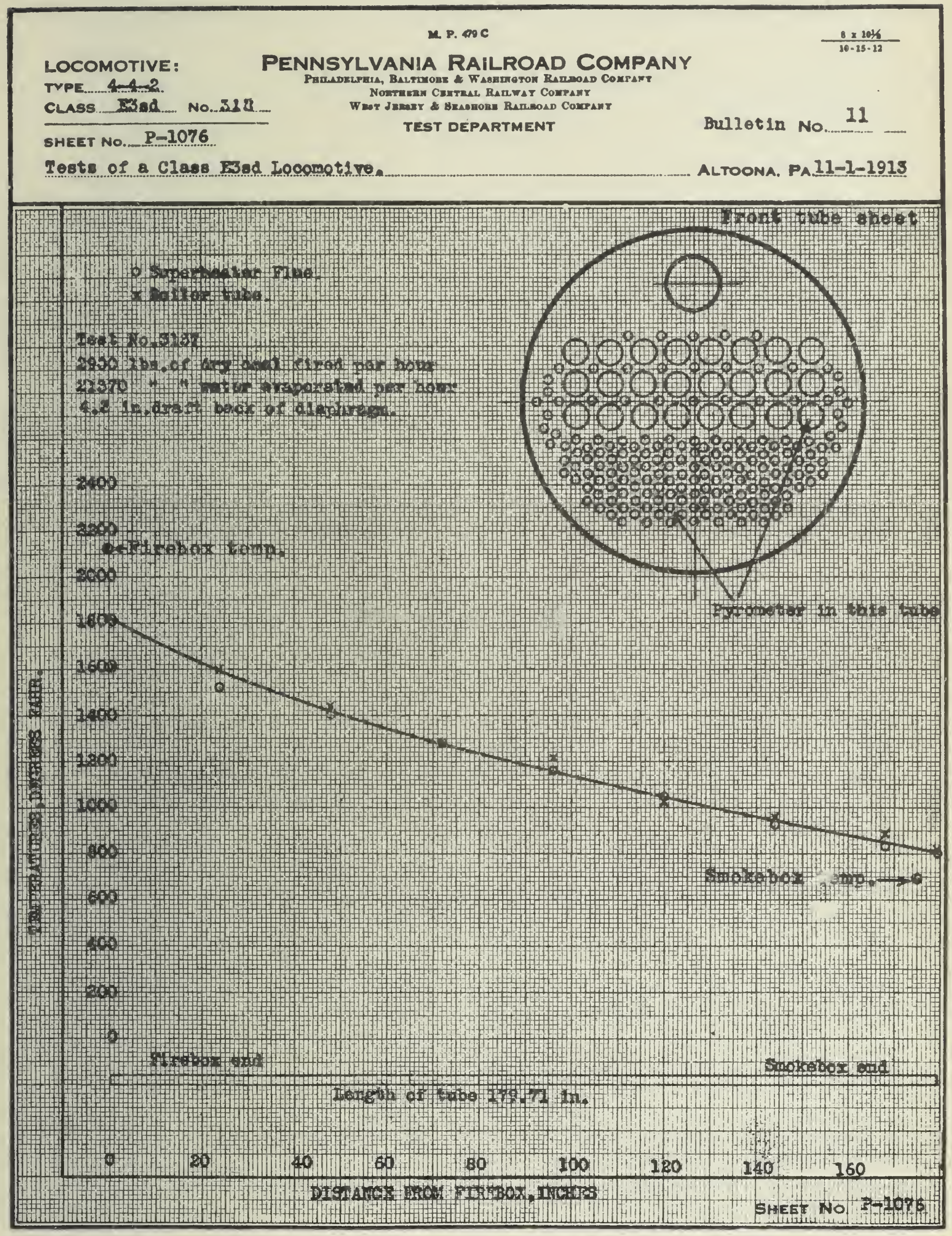

Fig. 24.

TEMPERATURES IN THE SUPERHEATER FLUE AND BOILER TUBE.

Temperatures for a rate of coal burning of 2900 pounds per hour.

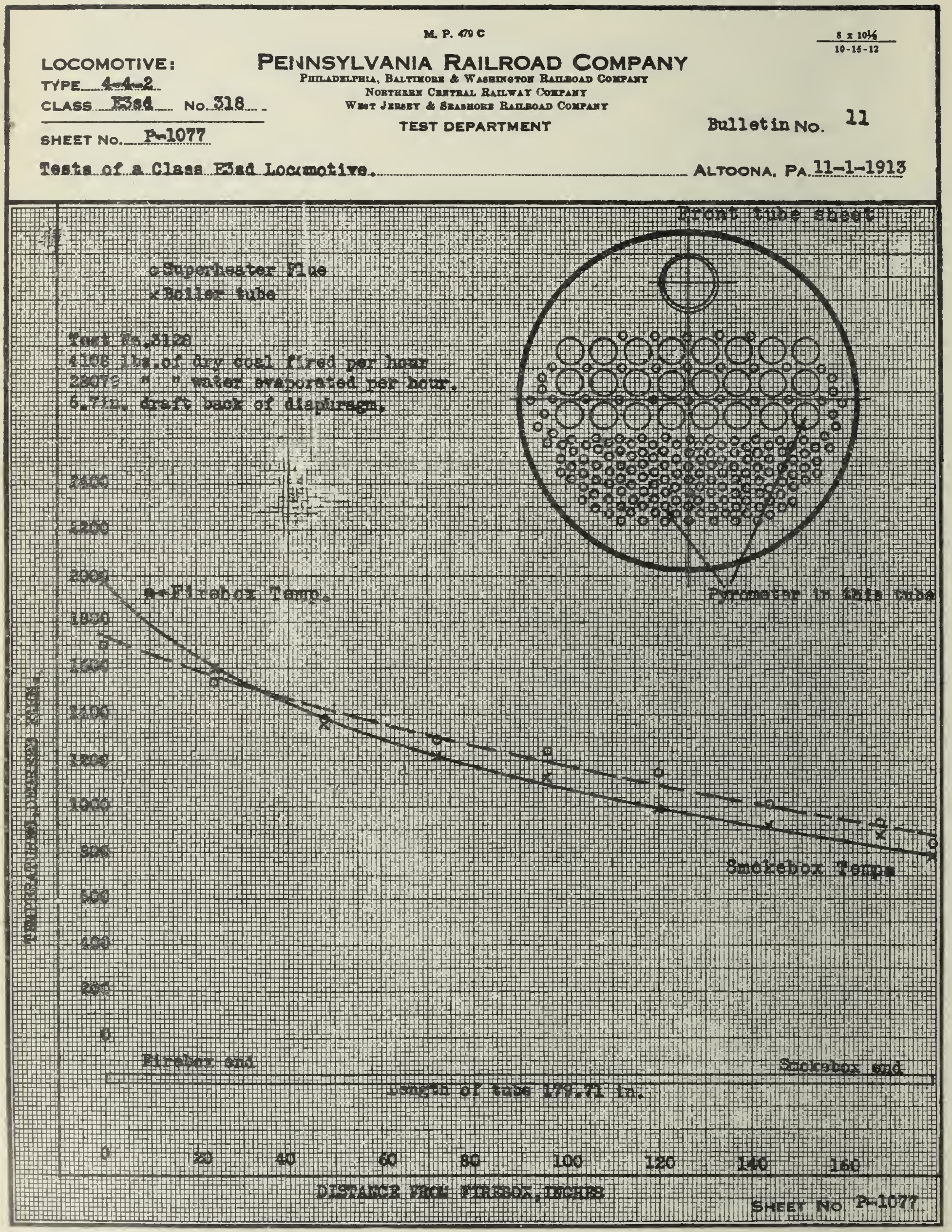

Fig. 25.

TEMPERATURES IN THE SUPERHEATER FLUE AND BOILER TUBE.

Temperatures for a rate of coal burning of 4100 pounds per hour.

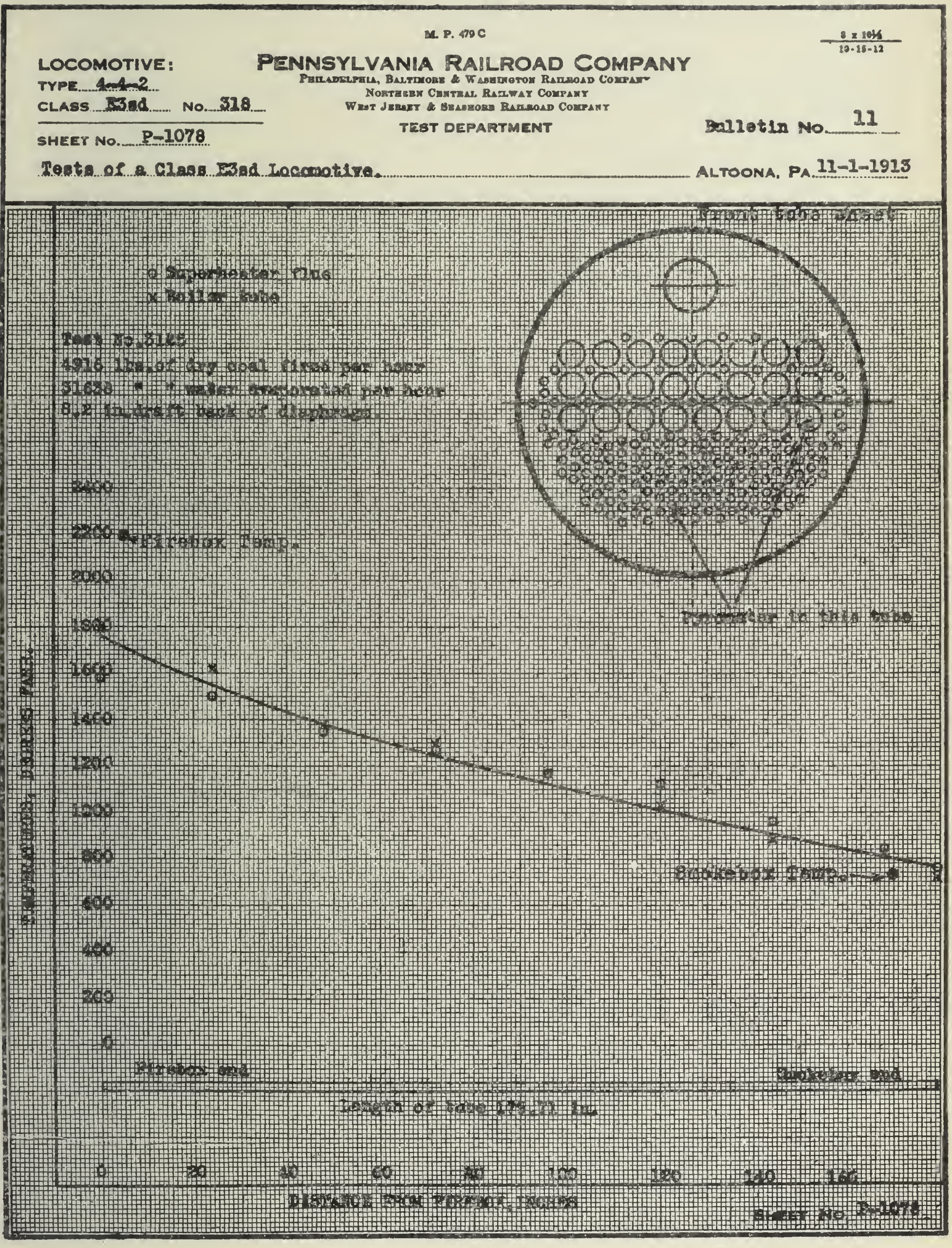

Fig. 26.
TEMPERATURES IN THE SUPERHEATER FLUE AND BOILER TUBE.
Temperatures for a rate of coal burning of 4900 pounds per hour.

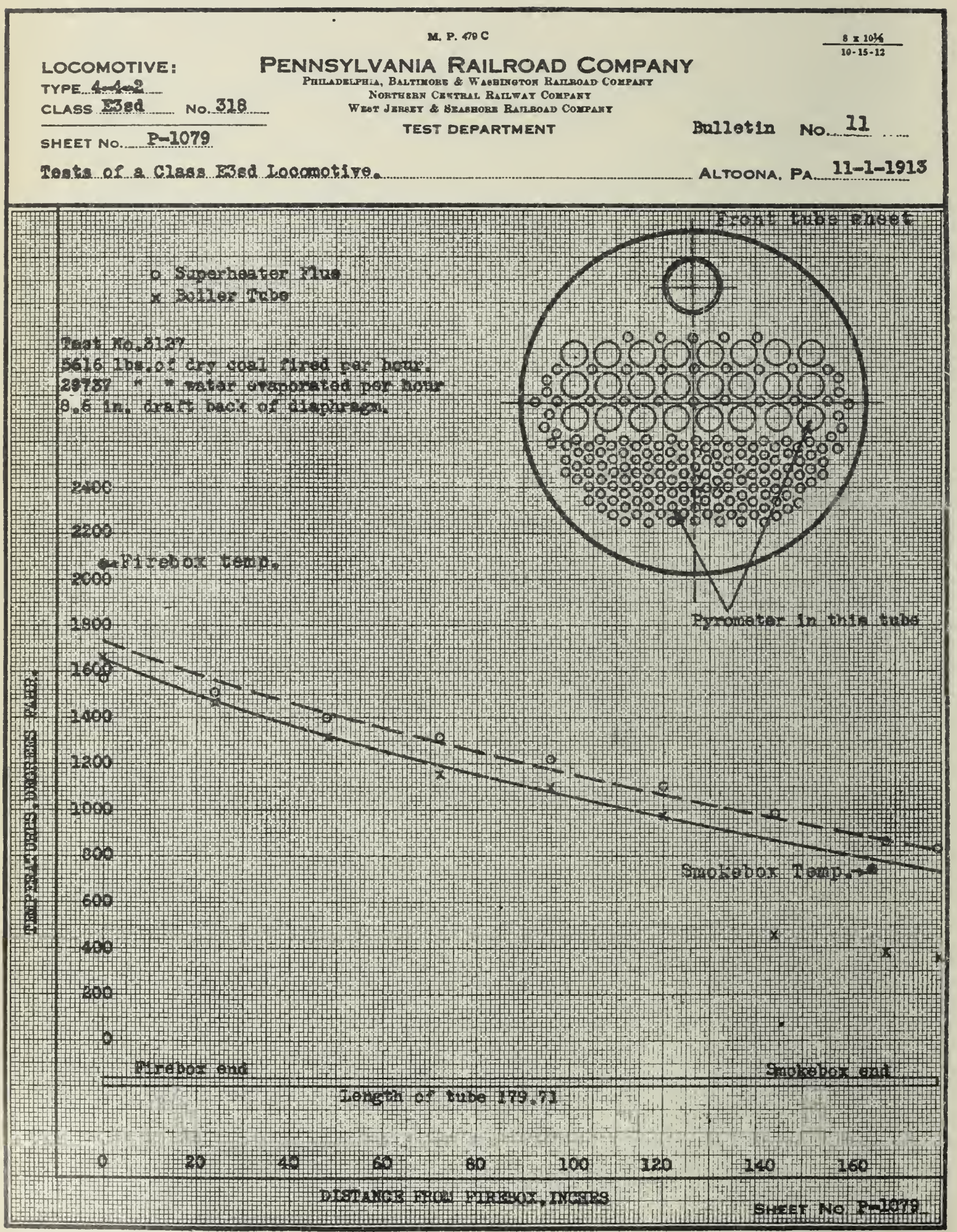

Fig. 27.

TEMPERATURES IN THE SUPERHEATER FLUE AND BOILER TUBE.

Temperatures for a rate of coal burning of 5600 pounds per hour.

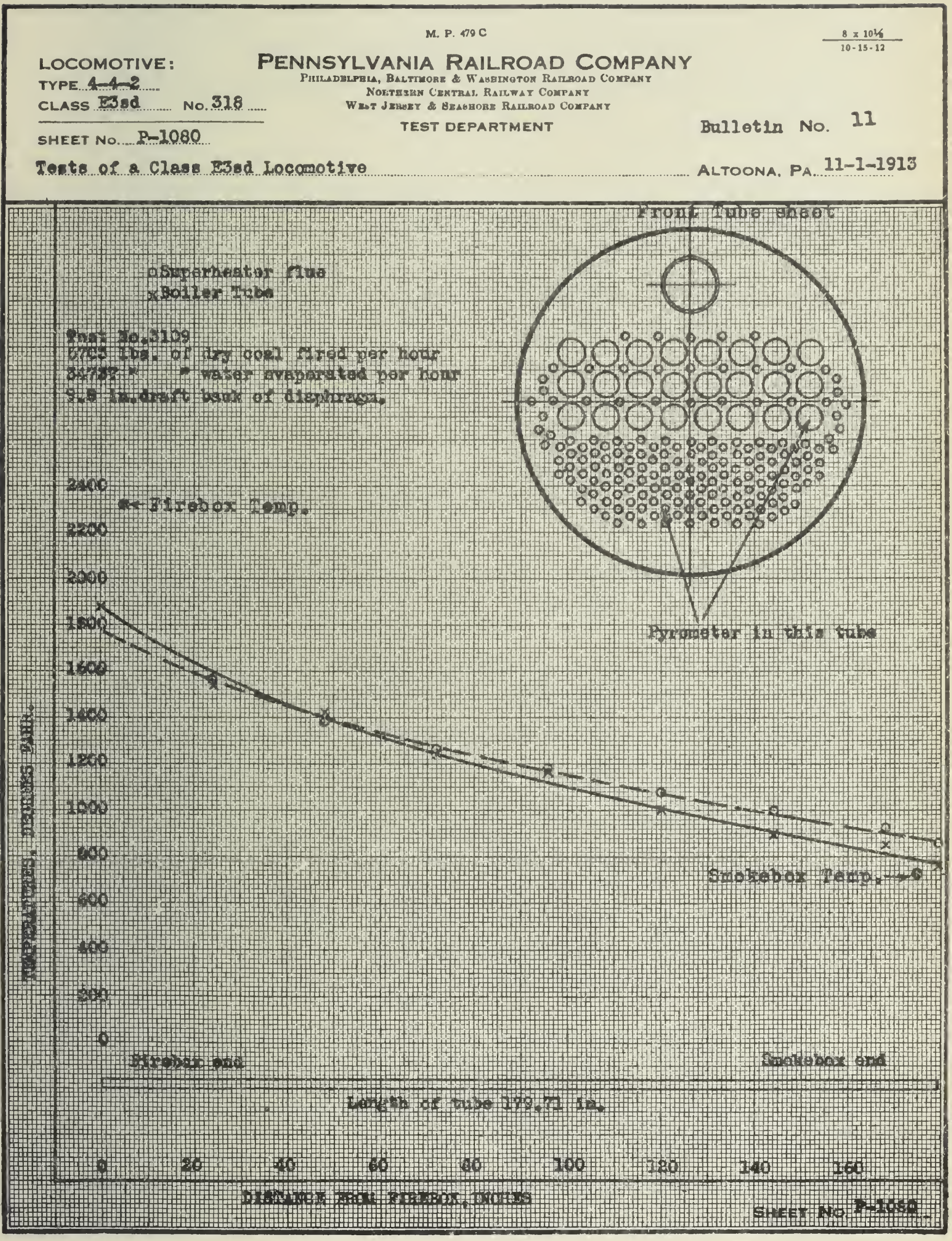

Fig. 28.

TEMPERATURES IN THE SUPERHEATER FLUE AND BOILER TUBE.

Temperatures for a rate of coal burning of 5700 pounds per hour.

102. The temperatures in the following table were obtained from the boiler tube temperature diagrams. These are shown in Figs. 23 to 28 inclusive in this Bulletin and Figs. 32 to 36 in Bulletin No. 21.

103. Table of temperature changes in tubes in an E6s and E3sd locomotive.

Test No.		Draft Inches of Water		Pounds of Water Evaporated Per Hour		Coal Fired, Pounds Per Hour		Temperature Drop Between Firebox and Smokebox		Difference in Temperature Drop Between the Two Boilers.
E3sd	E6s	E3sd	E6s	E3sd	E6s	E3sd	E6s	E3sd	E6s	
3136	2818	2.9	2.1	19316	19008	2452	2170	1000	800	200
3137	2819	4.3	3.0	21370	25667	2900	3092	1020	750	270
3128	2815	6.7	5.1	28079	31825	4108	4580	1180	860	320
3125	....	8.2	....	31638	....	4916	....	1000	....	....
3127	....	8.6	....	29737	....	5616	....	940	....	....
3109	2820	9.8	6.4	34737	38812	5703	5888	1100	840	260

104. The average temperature change or drop for the boiler tubes of the E3sd locomotive was 1040 degrees Fahr., while through the tubes of the E6s locomotive the drop was 813 degrees Fahr., thus, the difference in the temperature drop in the boiler tubes of the two locomotives which differ in length and arrangement is 227.5 degrees in favor of the longer E3sd locomotive boiler tube. It must be borne in mind, however, that the ratios of fire-tube surface to firebox heating surface are not the same in the two cases, the E6s locomotive, due to its combustion chamber, has a proportionally larger firebox heating surface than the E3sd, which could account for at least some of this difference.

105. The following table is arranged and presented to show what takes place in the tubes of the E3sd and E6s locomotive boilers when the rate of combustion ranges from approximately 2000 to 5800 pounds of coal per hour.

106. The E3sd tube is 179.71 inches or 9.4 per cent. longer than the E6s tube which is 164.31 inches long.

TEMPERATURE DROP PER INCH OF TUBE LENGTH BY TWENTY-INCH INCREMENTS. E3SD AND E6S BOILERS.

Inches of Tube Length from Firebox Toward Smokebox	Coal Rate							
	2000 to 2500		3000		4000 to 4500		5800	
	E3sd	E6s	E3sd	E6s	E3sd	E6s	E3sd	E6s
0 to 20	12	13	10	14	16	13	12	14
20 to 40	8	8	8	7	11	8	9	8
40 to 60	7	5	6	5	7	6	7	6
60 to 80	5	4	5	4	6	4	6	4
80 to 100	5	3	5	2	5	4	5	3
100 to 120	4	3	5	2	4	3	5	3
120 to 140	4	2	4	2	4	3	4	2
140 to 160	3	2	4	1	3	3	4	2
160 to 180	2	....	4	....	3	....	4	....
Draft in inches of water	2.9	2.1	4.3	3.0	6.7	5.1	9.8	6.4

107. While the table does not show the actual amount of heat taken up by the tube, it is a relative indication of what might be expected of the length of a boiler tube and the probable proportion of heat absorbed by it, per inch of length.

108. It is noticeable that the figures for the E3sd tube are larger than those for the E6s boiler tube. This is partly due to the probably lower velocity of the gases through the longer tube, due to the increased resistance offered by it. Further, in view of the fact that the combustion rates, as shown in the table above, are similar for both the E3sd and E6s locomotives and that their respective grate areas differ in area by but 0.53 square feet, it may reasonably be assumed that the volumes of gases resulting from combustion are nearly alike. Consequently the higher draft and higher temperature shown for the E3sd locomotive are no doubt due to the movement of the gases through a longer tube. Also it is possible that the somewhat smaller fire tube area of the E3sd boiler is partly responsible for this higher draft and temperature.

109. It seems true, from the low figures representing the E3sd locomotive boiler tube at its extreme end, 160 to 180 inches, that the limit of tube length for this locomotive has been reached, namely 15 feet. Should this length be exceeded the benefit to be derived would be inappreciable compared with the disadvantage incurred through slower combustion, for the average drop in temperature per inch of length is but a little over two degrees. At the same time the greater length would require greater draft at the expense of more back pressure on the engines.

110. This subject has also been discussed in Bulletin 21, pages 51 to 53 inclusive.

Heat Balance.

111. The heat balance given in Table X was calculated from the smokebox gas analysis, shown in Table VI, columns 253 to 256 inclusive. It agrees with the recommended practice of the American Society of Mechanical Engineers.

112. The results are shown graphically in Fig. 29. The largest item is the heat absorbed by the boiler, which shows a gradual decrease as the rate of combustion increases, and which at the maximum rate of combustion amounted to but 52 per cent.

113. The heat carried away in the gases of combustion was the largest single loss. The temperature of these escaping gases ranged from 433 to 748 degrees Fahr.

114. The loss of heat due to the presence of carbon monoxide, a product of incomplete combustion, is not large. It appears greatest when the combustion rate is above 5000 pounds of coal per hour.

115. The unaccounted for losses are radiation, and the combustible hydro-carbon gases which escaped unburned.

116. The dotted line represents the average boiler efficiency for all of the tests, and is similar to the curve in Fig. 20.

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8 x 10½
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LOCOMOTIVE:
TYPE 4-4-2
CLASS E3sd No. 318

PENNSYLVANIA RAILROAD COMPANY
PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY
TEST DEPARTMENT

Bulletin No. 11

SHEET NO. P-1081

Tests of a Class E3sd Locomotive. ALTOONA, PA. 11-1-1913

HEAT BALANCE BASED ON DRY COAL

Test No.	Dry Coal Fired Per Hour	Heat Absorbed by Boiler	Heat Loss Due to: Evap. of Moisture in Coal	Steam Formed by burning Hydrogen	Heat in Dry Gases	Carbon Monoxide	Heating Moisture in Air	Sparks	Radiation and Un-accounted For	Total	Calorific Value Of One Pound of Dry Coal
	Pounds	B.t.u.	B.t.u.	B.t.u.	B.t.u.	B.t.u.	B.t.u.	B.t.u.	B.t.u.	B.t.u.	B.t.u.
3136	2452	10170	26.6	624	2071	162	170.8	379.1	977.5	14581	14581
3119	3219	9384	23.2	627.5	1868	527	130.0	670.5	1035.8	14266	14266
3135	3663	9141	26.9	630.8	1929	649.6	163.9	729.1	1310.7	14581	14581
3128	4108	8908	27.0	633.7	2051	304.5	195.5	1181.1	1280.2	14581	14581
3125	4916	8394	23.5	638	2584	253.7	157.0	1426.6	789.2	14266	14266
3124	5491	7831	23.6	637	1959	893.2	179.8	1569	1173.4	14266	14266
3139	5977	7482	27.3	640.5	2260	385.7	159.7	1647	1978.8	14581	14581
	Pounds	%	%	%	%	%	%	%	%	%	%
3136	2452	69.7	0.17	4.29	14.25	1.11	1.17	2.6	6.71	100.00	100
3119	3219	65.7	0.16	4.39	13.09	3.68	0.91	4.7	7.38	100.01	100
3135	3663	62.7	0.18	4.32	13.22	4.45	1.12	5.0	8.99	99.98	100
3128	4108	61.1	0.19	4.34	14.1	2.08	1.34	8.1	8.75	100.00	100
3125	4916	58.6	0.16	4.47	18.1	1.77	1.10	10.0	5.53	99.7	100
3124	5491	54.8	0.17	4.46	13.7	6.25	1.26	10.9	8.46	100.00	100
3139	5977	51.3	0.19	4.39	15.4	2.64	1.09	11.3	13.69	100.00	100

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Table X.

HEAT BALANCE BASED ON DRY COAL.

This heat balance is computed according to the A.S.M.E. code for boiler tests, and includes representative tests in which the rates of firing range from minimum to maximum.

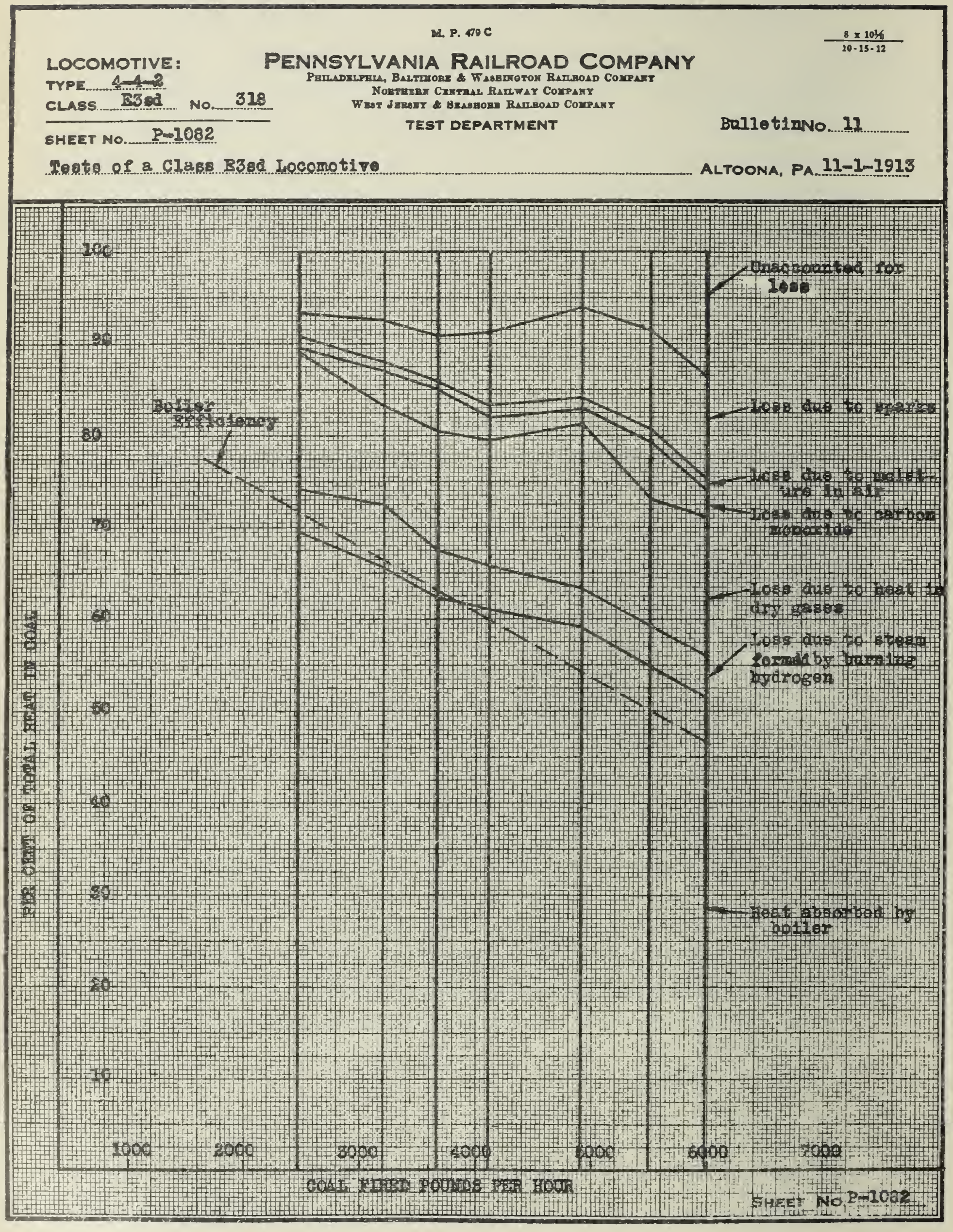

Fig. 29.

HEAT BALANCE.

This diagram shows the heat losses throughout a range of combustion rates between about 2500 and 6000 pounds of coal fired per hour.

PERFORMANCE OF ENGINES.

General Conditions.

117. The general conditions governing the tests pertaining to the engines are given in Table XI. The tests in the Table are arranged in groups according to speed with each group arranged in order according to cut-off. The various speeds in r.p.m. and the nominal cut-offs under which the tests were run are shown under "Test Designation." As indicated by letter "F" all of the tests were run with a fully open throttle.

118. Further, by referring to Table XI, one may ascertain the duration of each test in minutes, the speed in r.p.m. and also in m.p.h., the actual cut-off as measured from the indicator card, the steam pressures in boiler and branch pipe and the amount of superheat in the branch pipe in degrees Fahrenheit.

119. Each speed was maintained as nearly uniform as possible during a test, and was controlled with no appreciable error. The cut-off varied for a given position of the reverse lever with the speed (column 272). The safety valves were set at 205 pounds and only when the boiler was forced did the pressure show any appreciable drop. The superheat in the branch pipe followed the same general rule that prevails with this type of superheater, namely: the degree of superheat increased at the same speed with an increase of cut-off and also increased at the same cut-off with an increase of speed.

Superheat in Branch Pipe and Exhaust.

120. The superheat in the exhaust steam (Fig. 30) gradually increased as the superheat in the steam passing through the branch pipe increased from 110 to 210 degrees Fahr. At this point the rise in temperature was considerably more rapid up to 254 degrees Fahr., the maximum.

Superheat and Temperature of Cylinder Walls.

121. In order to expand steam of 205 pounds (220 absolute) down to and release dry and saturated at atmospheric pressure

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LOCOMOTIVE:
TYPE 4-4-2
CLASS E3sd No. 318

SHEET NO. P-1083

PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

TEST DEPARTMENT

Bulletin No. 23

Tests of a Class E3sd Locomotive. ALTOONA, PA. 11-1-1913

ENGINE TEST CONDITIONS

Test No.	Test Designation	Duration of Test Mins.	Revolutions per Minute	Speed in Miles Per Hour	Cut-off Per cent of Stroke	Steam Pressure In Boiler Pounds per Square Inch	Steam Pressure In Branch Pipe Lb. per Square Inch	Superheat In Branch Pipe Degrees Fahr.
			198	199	272	217	220	230
3111	120-20-F	120	120	28.01	18.3	203.6	198.2	118.15
3112	120-30-F	120	120	28.01	25.2	205.2	199.2	138.37
3137	120-40-F	120	120	28.01	34.4	206.0	198.0	192.56
3121	160-30-F	120	160	37.34	26.4	205.5	196.5	199.39
3113	160-35-F	120	160	37.34	31.5	205.5	197.2	161.69
3114	160-45-F	90	160	37.34	41.1	205.5	192.6	175.07
3133	160-50-F	60	160	37.34	42.8	203.4	189.3	211.67
3136	200-20-F	120	200	46.68	21.2	205.8	198.8	195.44
3115	200-35-F	120	200	46.68	32.7	205.0	193.2	179.26
3134	200-35-F	60	200	46.68	31.5	205.1	193.0	218.04
3135	200-35-F	60	200	46.68	31.1	206.0	194.7	227.37
3124	200-45-F	90	200	46.68	41.5	203.0	186.0	232.32
3117	240-20-F	120	240	56.02	22.8	206.0	198.8	208.44
3116	240-35-F	90	240	56.02	33.4	205.4	192.7	213.96
3109	240-45-F	60	240	56.02	42.1	195.9	175.6	193.44
3139	240-45-F	60	240	56.02	41.9	196.4	178.0	253.84
3119	280-20-F	90	280	65.35	25.7	206.0	197.4	221.08
3122	280-30-F	60	280	65.35	31.1	197.1	185.4	227.38
3125	280-35-F	60	280	65.35	34.4	205.7	191.1	226.80
3126	320-20-F	60	320	74.69	21.2	205.6	195.1	207.43
3128	320-25-F	60	320	74.69	25.8	205.9	195.0	221.40
3127	320-30-F	60	320	74.69	30.8	204.5	190.8	228.29
3142	360-25-F	30	360	84.02	31.2	196.8	184.5	220.83
3143	360-25-F	30	360	84.02	31.6	205.8	191.0	221.47

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Table XI.
ENGINE TEST CONDITIONS.
The speed, cut-off, steam pressure and superheat are shown for each of the tests.

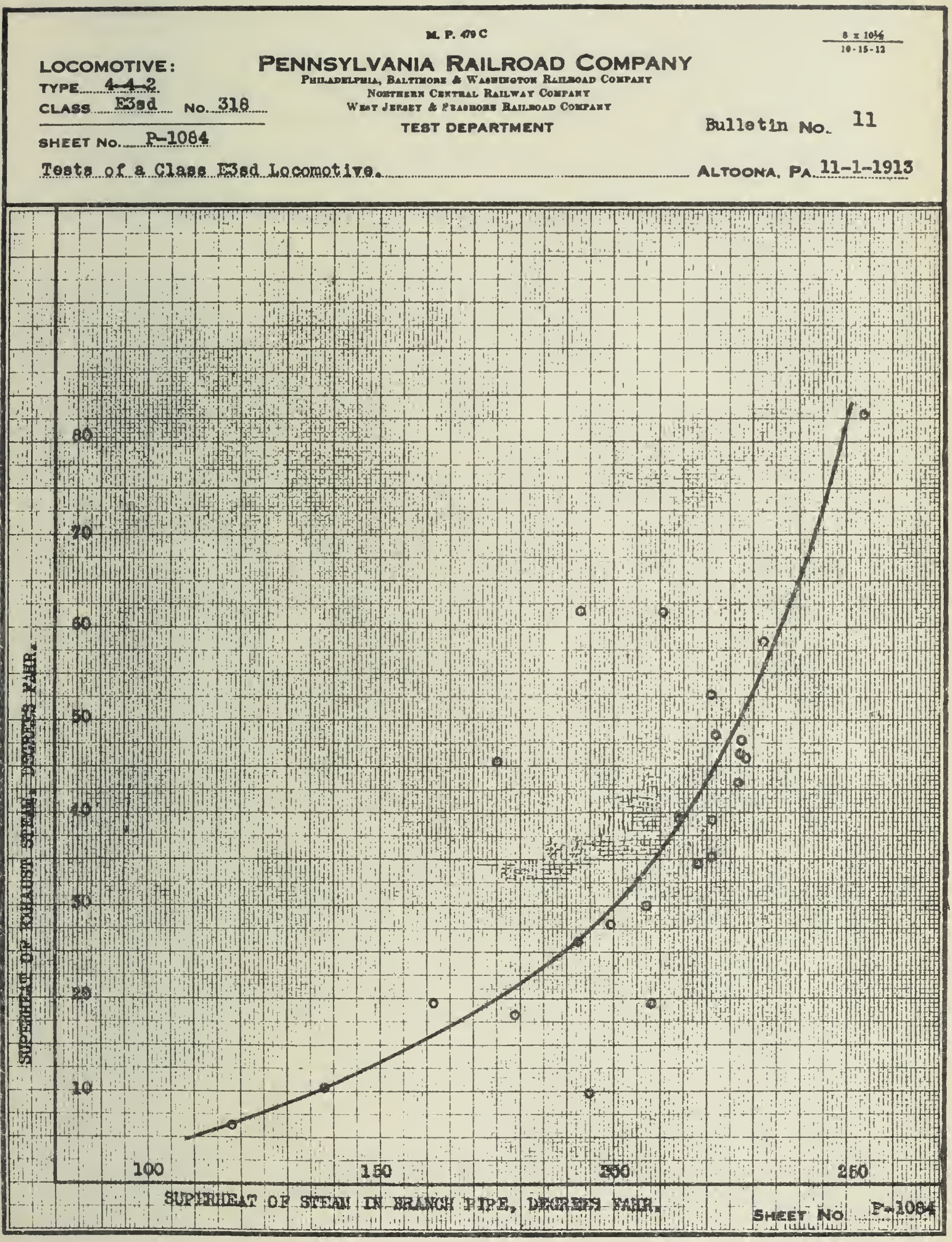

Fig. 30.
BRANCH PIPE AND EXHAUST SUPERHEAT.
The superheat in the exhaust steam increases gradually until the superheat in the branch pipe approximates 210 degrees, whereupon the superheat in the exhaust rises more rapidly.

would require the steam originally to be heated to between 430 degrees and 435 degrees at the least, this corresponding to adiabatic expansion, but in as much as there is some back pressure, a lower temperature, say from 360 degrees to 400 degrees, would allow steam to exhaust dry and saturated even if release did not occur until the end of the stroke; however, since the steam is released at 50 pounds (65 absolute) or above, the amount of superheat necessary for the exhaust to be dry and saturated is lower still.

122. The minimum average degrees of superheat found in the exhaust was 10.3 and the maximum average 72.2, corresponding respectively to steam in branch pipe as observed of 194.1 degrees and 236.7 degrees of superheat, showing, as does also Fig. 30 following, that the superheat in the exhaust is higher, the higher the superheat in the branch pipe and that the increase in exhaust superheat is more marked as that in the branch pipe increases above say 210 degrees. This indicates, from the point of view that superheat in the exhaust is wasteful, not that there is no advantage in a higher superheat in the branch pipe than 180 degrees to 210 degrees, but that the full value of the superheat is not being realized due to the cut-off being longer than would be the case if larger cylinders could be provided.

123. In Bulletin 19 ("Tests of a Class K29 Locomotive," paragraphs 119 and 120 and Fig. 51 of that Bulletin) some information is given relative to the temperature of the cylinder walls compared with the temperature of the steam in the branch pipe. Data in this respect was not taken from the E6s locomotive or from the E6, but readings were obtained of the temperature of the front cylinder head of E3sd locomotive No. 318 which followed the E6s on the plant, as information for this Bulletin. These temperatures from the E3sd locomotive are given in Table XII and show the drop in temperature of the front cylinder head from the instant of stopping the test with the inside of the cylinder exposed to the open exhaust passage through the valve, and include one test at 120 revolutions and 30 per cent. cut-off, another test at 200 revolutions and 35 per cent. cut-off and two tests at 240 revolutions, one of which was at 40 per cent., the other at 45 per cent. cut-off, thus giving a range of superheat in the branch pipe from 175 degrees to 260 degrees.

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LOCOMOTIVE:
TYPE 4-4-2
CLASS E3sd No. 318

PENNSYLVANIA RAILROAD COMPANY
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NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-1085

TEST DEPARTMENT

Bulletin No. 11

Tests of a Class E3sd Locomotive. ALTOONA, PA. 11-1-1913

DROP IN TEMPERATURE OF CYLINDER HEAD (Steam Surface)
E3sd Locomotive 318.

Test Number Test Designation,	3144 120-30-F	3145 200-35-F	3147 240-40-F	3146 240-45-F
Pressure in Pounds Per Square Inch.				
In boiler,	205.2	205.1	200.0	192.2
" branch pipe,	198.7	190.4	182.3	174.2
Mean forward pressure,	97.25	103.14	101.61	97.32
" back " and compression pressure,	8.49	15.32	20.46	20.24
" effective pressure,	88.76	87.82	81.15	77.08
Superheat, Degrees Fahrenheit.				
In Branch Pipe,	175.1	228.0	259.7	257.5
Temperature of Steam				
In branch pipe (Superheated Steam), Degrees F.	562.5	612.0	640.3	634.7
of saturated steam of same pressure,	387.4	384.0	380.6	377.2
" " " " mean forward pressure,	336.1	340.0	339.0	336.2
" " " " " back pressure,	236.0	250.4	259.6	259.2
Mean of mean forward and mean back pressure,	286.1	295.2	299.3	297.7
Temperature of Front Cylinder Head (Steam Surface)				
(a) Actual, degrees F.	394.0	450.0	462.0	466.0
(b) Below that of steam in branch pipe,	168.5	162.0	178.3	168.7
(c) Above that of saturated steam of same pressure,	7.4	62.0	74.4	78.4
(d) " " " " " " M.E.P.	101.3	88.8	81.3	79.5
Drop in Temperature Right Front Cylinder Head (Close to inside Surface)				
Total in 15 minutes, Degrees F.,	40	40	47	48
Average degrees drop per minute,	2.33	2.8	3.15	3.2
Drop in 1st 15 seconds,	—	1	1	1
" " 2nd " "	—	1	0	0
" " 3rd " "	—	0	1	2
" " 4th " "	—	0	1	0
Drop in one minute,	2	2	3	3
Drop in 5th 15 seconds,	—	2	1	1
" " 6th " "	—	0	0	0
" " 7th " "	—	0	1	2
" " 8th " "	—	1	1	1
Drop in 2nd minute,	2	3	3	4
" " 2 minutes,	4	5	6	7
Average drop in 2 minutes, per minute,	2	2.5	3	3.5

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Table XII.

DROP IN TEMPERATURE OF CYLINDER HEAD (STEAM SURFACE).

This table shows the temperature measured at the front cylinder head on the E3sd superheated steam locomotive at different speeds and cut-offs. These temperatures represent the different working temperature of the cylinder walls.

124. The temperature of the front cylinder head given in the Table as actual, represents as nearly as possible, in this case, the maximum average working temperature of the cylinder walls. It will be seen that this temperature ranged in the four tests from 162 degrees to 178 degrees below the temperature of the superheated steam in the branch pipe and from 7.4 degrees to 78.4 degrees above the temperature of the corresponding saturated steam of branch pipe pressure and from 101.3 degrees to 79.5 degrees above the temperature of saturated steam of the actual mean effective pressure in the cylinders and from 158 degrees to 207 degrees above the temperature of saturated steam of average back pressure. This seems to indicate the possibility that a less superheat than 162 degrees would result in a cylinder wall temperature below the average temperature of saturated steam of branch pipe pressure, but that the cylinder wall temperature actually obtained would not prevent the steam being superheated at any time during the stroke or in the exhaust passage.

125. The drop in temperature within 15 minutes after the close of the test amounted to from 40 degrees to 48 degrees or from 2.3 degrees to 3.2 degrees per minute, at a fairly uniform rate, averaging from 2 degrees to 3 degrees for the first minute and from 2 degrees to 4 degrees the second minute. Apparently the rate of drop for the first few seconds was not so rapid as for the latter portion of the test, possibly due to the time lost at the end of the test in adjusting the valve so that it was open to the exhaust. An opportunity for further investigation in this direction will be had in the near future, which will enable readings of the temperature at different points in the cylinder walls to be taken from the same locomotive while using different qualities of steam ranging from saturated to highly superheated, which should give still further valuable information, particularly as to the amount of superheat desirable and also as to that lost due to cooling action of the cylinder walls; the indication here is that the rate of cooling is slow, but information is lacking as to the amount of heat lost per stroke at any given speed, due to drop in skin temperature of the cylinder walls, and as to what extent this drop causes the drop of approximately 170 degrees in the steam temperature from that in the branch pipe to the average

temperature of the cylinder walls, rather than that the latter is due to useful work done by the steam.

Superheat in Branch Pipe and Indicated Horse-Power.

126. The degree of superheat in the branch pipe within the range of the power output of this locomotive is shown in Fig. 31. The indicated horse-power increased from 747 to 1959 i.h.p., and the range of superheat within these limits is expressed by a straight line, clearly indicating that the degree of superheat in the branch pipe increased directly as the power of the locomotive increased.

127. While the indicated horse-power and the degree of superheat bear some relation to each other, the degree of superheat is directly dependent on the steam pressure, superheater size, volume of steam flow and the temperature of the gases around the superheater units as previously mentioned in Par. 103, Bulletin No. 21.

Indicator Diagrams.

128. Figs. 32, 33 and 34 show a number of indicator diagrams that are representative for this locomotive. The test numbers, scale of pressure, speed in r.p.m. and m.p.h., nominal cut-off, and the indicated horse-power are shown with each diagram.

129. Each card is designated as taken on the right or left side of the locomotive and whether head or crank end. It will also be observed that steam chest diagrams are given for each indicator card taken on the left side of the locomotive.

130. The same characteristic feature observed in steam chest diagrams taken from other superheater locomotives when running at high speeds, namely, the variation in pressure at mid-stroke is likewise shown in these diagrams in Fig. 33. The pressure reaching 210 pounds is higher than the boiler pressure attained and recorded for these tests. As brought out in Bulletin No. 21, this unlooked for fluctuation is probably due to inertia of the steam in the passages from the boiler to the steam chest after cut-off.

131. It will be observed (Fig. 32) that for speeds of 200 r.p.m. or 46 m.p.h. and less, this rise in steam pressure did not occur. In each of the several steam chest diagrams the pressure line at the end of the stroke loops at a point which would coincide with the continuation of the true expansion line.

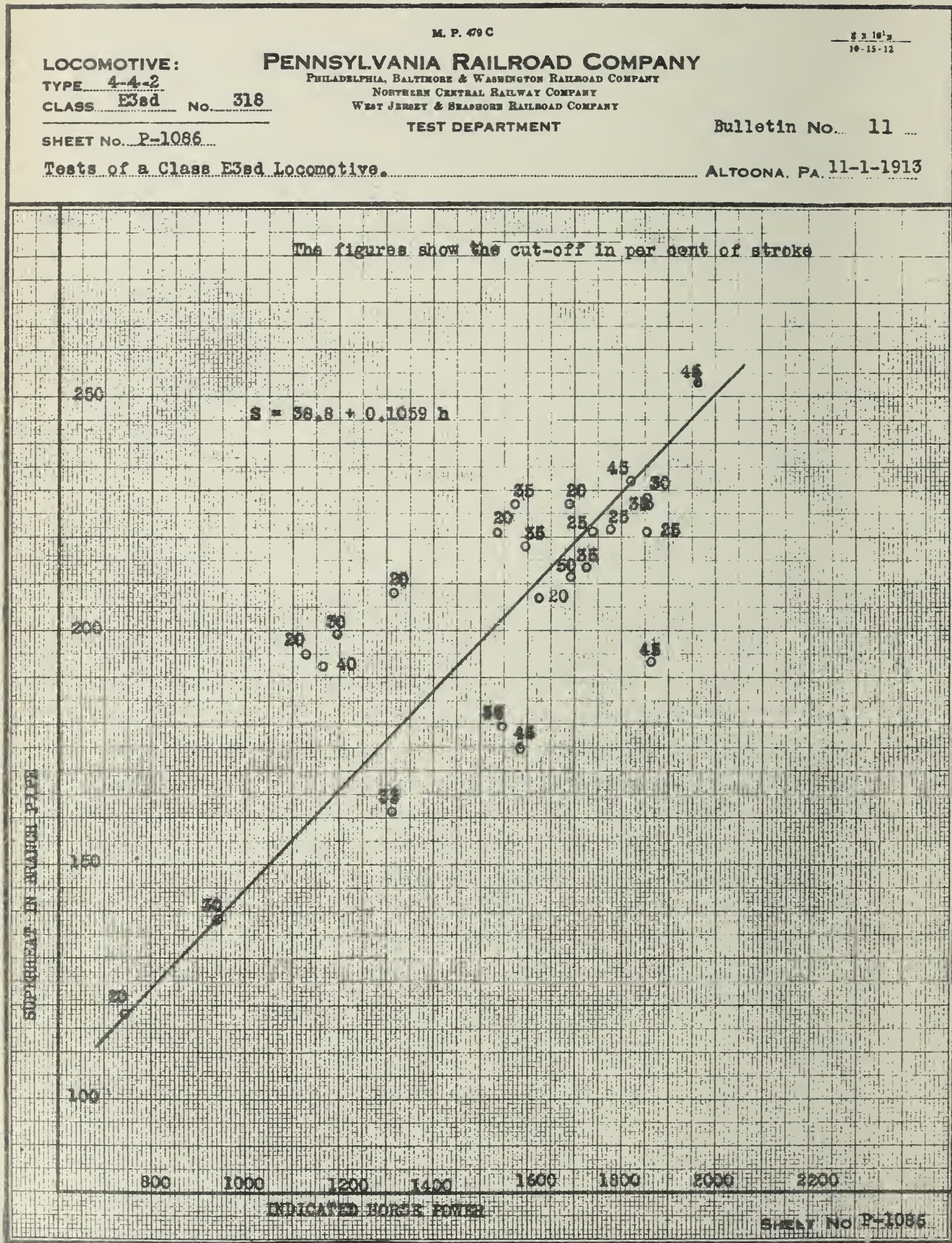

Fig. 31.

SUPERHEAT OF LIVE STEAM AND INDICATED HORSE-POWER.

The regular increase in superheat with the increase in the indicated horse-power is due to the increasing combustion rate, following a demand on the boiler for a greater steam supply.

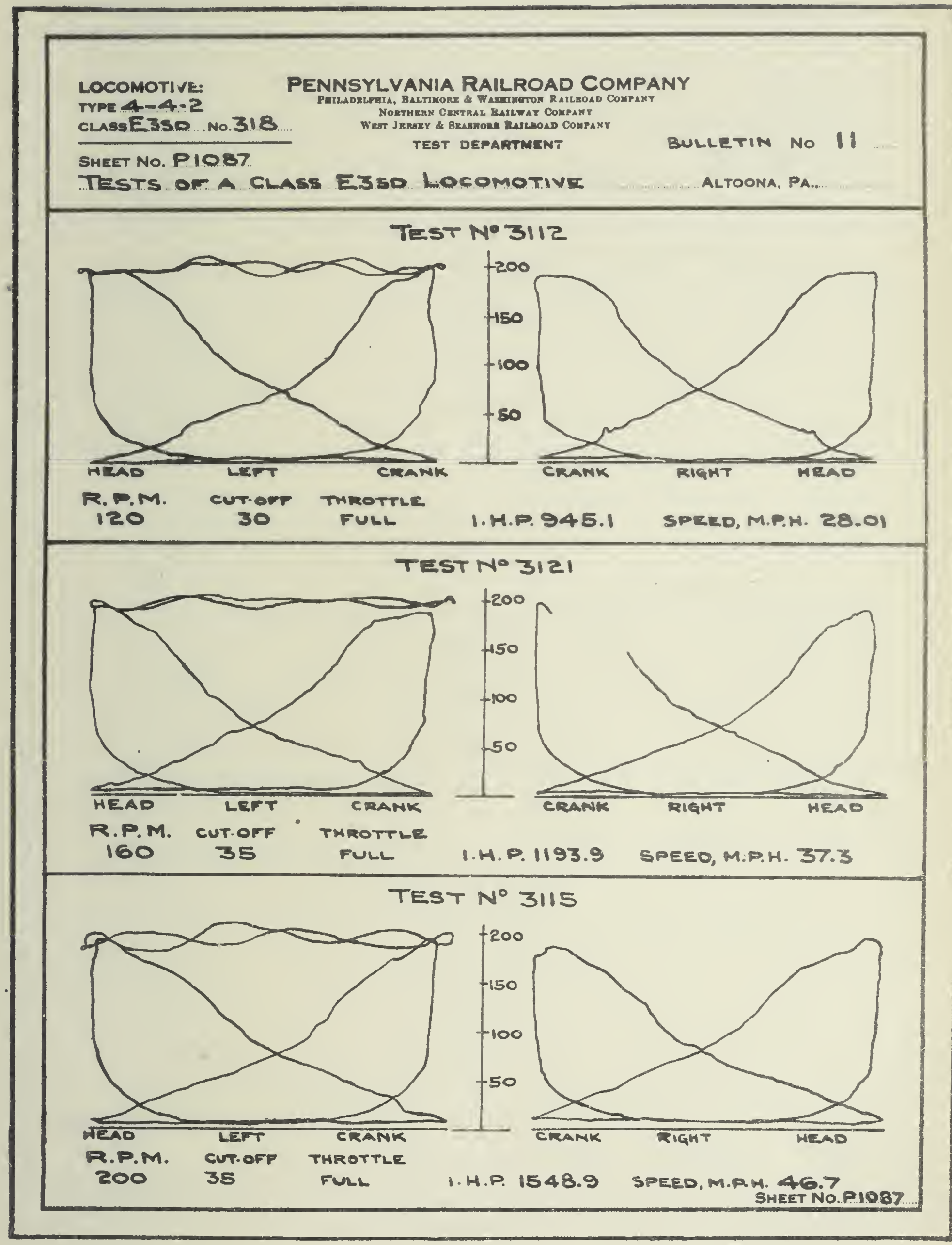

Fig. 32.

TYPICAL INDICATOR DIAGRAMS.

These diagrams were taken at speeds of 28, 37 and 46 miles per hour.

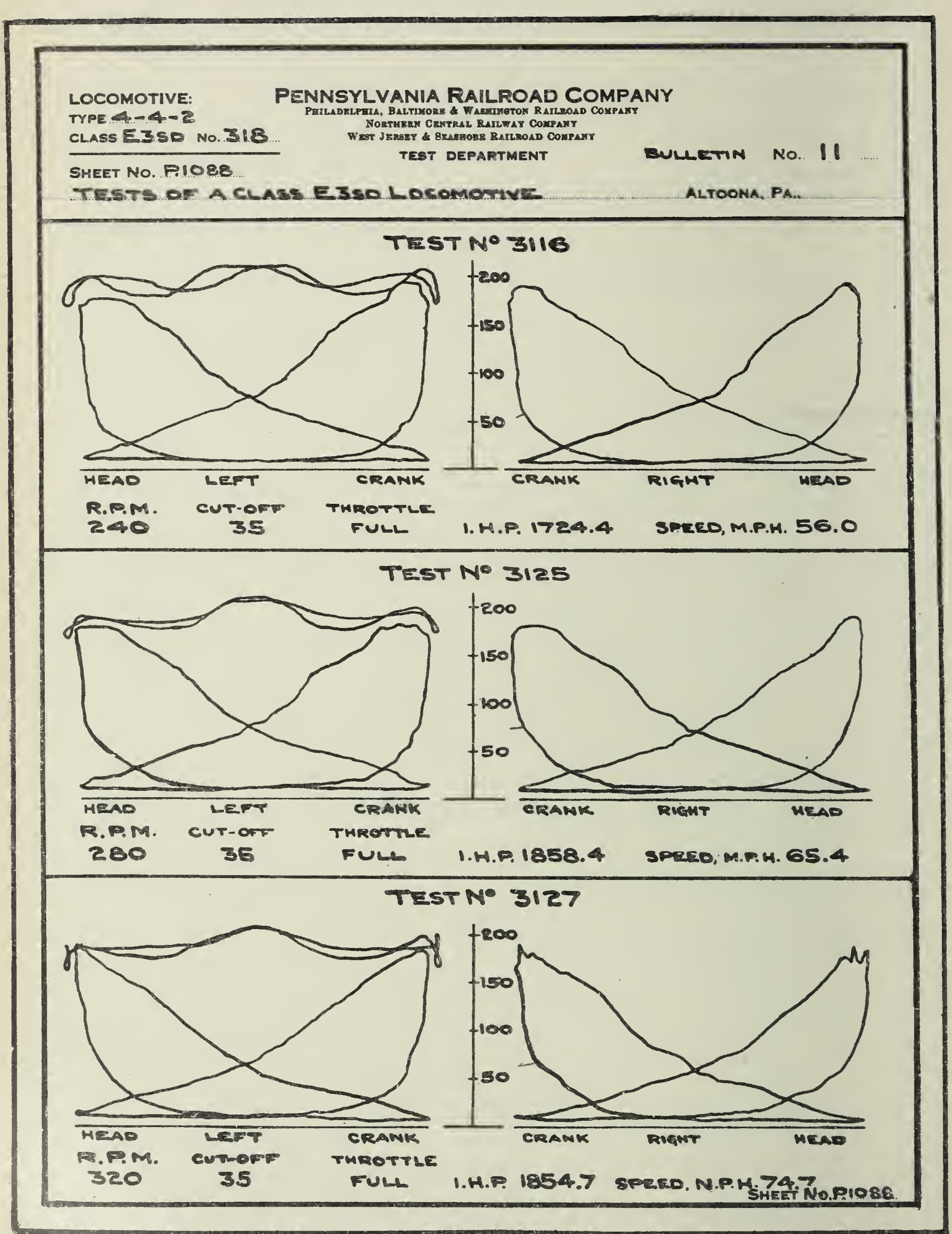

Fig. 33.
TYPICAL INDICATOR DIAGRAMS.
These diagrams were taken at speeds of 56, 65 and 75 miles per hour.

LOCOMOTIVE:
TYPE 4-4-2
CLASS E3sd No. 318

PENNSYLVANIA RAILROAD COMPANY
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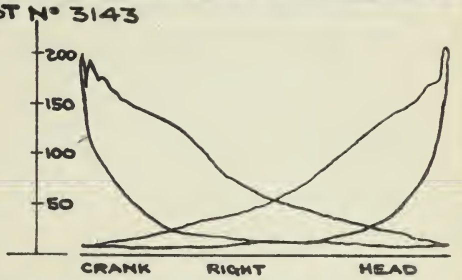
WEST JERSEY & SEASHORE RAILROAD COMPANY
TEST DEPARTMENT

BULLETIN No. 11

SHEET No. P.1089

TESTS OF A CLASS E3sd LOCOMOTIVE ALTOONA, PA.



R.P.M.	CUT-OFF	THROTTLE		
360	25	FULL	I.H.P. 1853.0	SPEED, M.P.H. 84.0

SHEET No. P.1089

Fig. 34.
TYPICAL INDICATOR DIAGRAM.
This diagram was taken at a speed of 84 miles per hour.

Indicated Horse-Power.

132. Table XIII is presented to show the performance of the engines of this locomotive. It gives the speed in r.p.m. the duration of the test in minutes, pounds of steam to the engines per hour, the mean effective pressure in pounds per square inch, the indicated horse-power, the dry coal per indicated horse-power hour in pounds, pounds of superheated steam per i.h.p. hour and the B.t.u. in the steam per i.h.p. hour. The table is arranged according to the indicated horse-power increase.

133. The indicated horse-power ranged from 747 at 28 m.p.h. with a nominal cut-off at 20 per cent. to a maximum of 1958 i.h.p. at 56 m.h.p. and 45 per cent. cut-off. At 56 m.p.h. with 45 per cent. cut-off the maximum capacity of the boiler was reached and above this speed and cut-off the power of the locomotive steadily diminished.

Drop in Pressure from Throttle to Branch Pipe.

134. Referring to Table XIV, it may be seen that the drop in pressure from throttle to branch pipe increased at like cut-offs with an increase in speed, and at the same speeds it increased with an increase in the cut-off.

Table XIV.

Nominal Cut-off in Per Cent.	Revolutions Per Minute						
	120	160	200	240	280	320	360
	Drop in Pressure—Pounds Per Square Inch						
20	5.4		7.0	7.2	12.7 11.3	10.5	
25						10.9	12.3 14.8
30	6.0	9.0				13.7	
35		8.3	11.8 12.1 11.3	12.7	14.6		
40	8.0						
45		12.9		20.3 18.4			
50		14.1	17				

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LOCOMOTIVE:
TYPE 4-4-2
CLASS E3sd No. 318

PENNSYLVANIA RAILROAD COMPANY
PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

TEST DEPARTMENT

SHEET NO. P-1090

Bulletin No. 11

Tests of a Class E3sd Locomotive.

ALTOONA, PA. 11-1-1913

INDICATED HORSE POWER

Test No.	Test Designation	Duration of Test Mins.	Steam to Engine Pounds Per Hour	Mean Effective Pressure Pounds per Square in.	Indicated Horse Power	Dry Coal Per indicated Horse Power Hour Pounds	Superheated Steam per Indicated Horsepower Hour pounds	B.t.u. in Steam Per Indicated Horsepower Hour
			214		379	380	381	
3111	120-20-F	120	14872	62.93	746.87	2.28	19.91	25236
3112	120-30-F	120	17828	79.65	945.11	2.37	18.86	24140
3136	200-20-F	120	18900	57.63	1129.14	2.17	16.74	22028
3137	120-40-F	120	20921	98.85	1161.4	2.53	18.01	23536
3121	160-30-F	120	20246	75.50	1193.9	2.12	16.96	22189
3113	160-35-F	120	23422	83.02	1313.8	2.25	17.83	22977
3117	240-20-F	120	20626	55.42	1315.6	2.07	15.68	20605
3119	280-20-F	90	22682	55.41	1534.2	2.10	14.78	19438
3115	200-35-F	120	26644	78.31	1548.9	2.61	17.20	22247
3135	200-35-F	60	25343	80.44	1574.8	2.33	16.09	21262
3114	160-45-F	90	29571	100.34	1588.2	3.08	18.62	24130
3134	200-35-F	60	25917	81.48	1596.1	2.80	16.24	21303
3126	320-20-F	60	24208	51.34	1624.03	2.33	14.91	19560
3122	280-30-F	60	26311	61.07	1690.5	2.55	15.55	20548
3133	160-50-F	60	30184	108.30	1691.6	3.24	17.79	23422
3116	240-35-F	90	28546	72.63	1724.4	2.55	16.55	21752
3128	320-25-F	60	27282	55.53	1738.9	2.36	15.69	19684
3142	360-25-F	30	27546	50.46	1776.96	2.89	15.50	20411
3124	200-45-F	90	32353	92.00	1820.6	3.02	17.77	23520
3143	360-25-F	30	28655	105.08	1852.95	2.94	15.46	20373
3127	320-30-F	60	29318	58.62	1854.7	3.03	15.81	20903
3125	280-35-F	60	31054	67.12	1858.4	2.65	16.71	22079
3109	240-45-F	60	32360	78.42	1861.8	3.06	18.46	24052
3139	240-45-F	60	33628	83.33	1958.50	3.05	17.17	22859

SHEET NO. P-1090

Table XIII.

INDICATED HORSE-POWER.

The indicated horse-power ranges from 746.87 at 120 revolutions per minute, or 28 miles per hour, to 1958.5 at 240 revolutions per minute, or 56 miles per hour. The steam consumption per indicated horse-power hour is as low as 14.91 and the coal consumption does not exceed 3.24 pounds.

135. In Fig. 35 this drop in pressure is plotted against the i.h.p. The curve indicates that the drop was gradual up to about 1600 indicated horse-power. The steam consumption at this power output reached 26,300 pounds per hour (Fig. 37), and the steam flow attained a maximum velocity of approximately 4840 feet per minute. Above this steam velocity, the drop in pressure tends to increase rapidly until the maximum indicated horse-power is reached.

136. The maximum drop in pressure for this locomotive was 20.3 pounds. It occurred when the weight of steam flow to the engines reached 32,360 pounds per hour, or a rate of flow of over 7000 feet per minute through the superheater units.

Steam to the Engines.

137. The steam to the engines per indicated horse-power hour shown in column 381, Table XIII, is plotted against the indicated horse-power (column 379) in Fig. 36 for the E3sd superheater locomotive. Above is shown a similar curve for the E2d saturated steam locomotive.

138. The diagram illustrates the economical performance of the superheater locomotive or the saving in the water per indicated horse-power hour above that obtained from a saturated steam locomotive having a cylinder 1.5 inches smaller in diameter. The saving effected increases with the increase in the power developed and ranged from 21.4 per cent. at 600 i.h.p. to 34.5 per cent. at 1400 i.h.p.

139. The increased consumption of steam per i.h.p. hour, at low horse-power, seems characteristic for this class of locomotive, namely, the E2a (Bulletin No. 5, Fig. 5), E2d and E3sd locomotives. The steam consumption drops off gradually as the power developed is increased. This is not so noticeable in the case of the E6s locomotive (Bulletin No. 21, Fig. 58), where the curve is more flat, nor is it as pronounced in the Pacific type K29 locomotive (Bulletin No. 19, Fig. 42).

140. Fig. 37 furnishes a curve showing the relation between the pounds of steam per hour and the indicated horse-power. The curve for the E6s locomotive given in Bulletin No. 21, Fig. 57, is a straight line showing a more direct relation between the power output and the steam consumption.

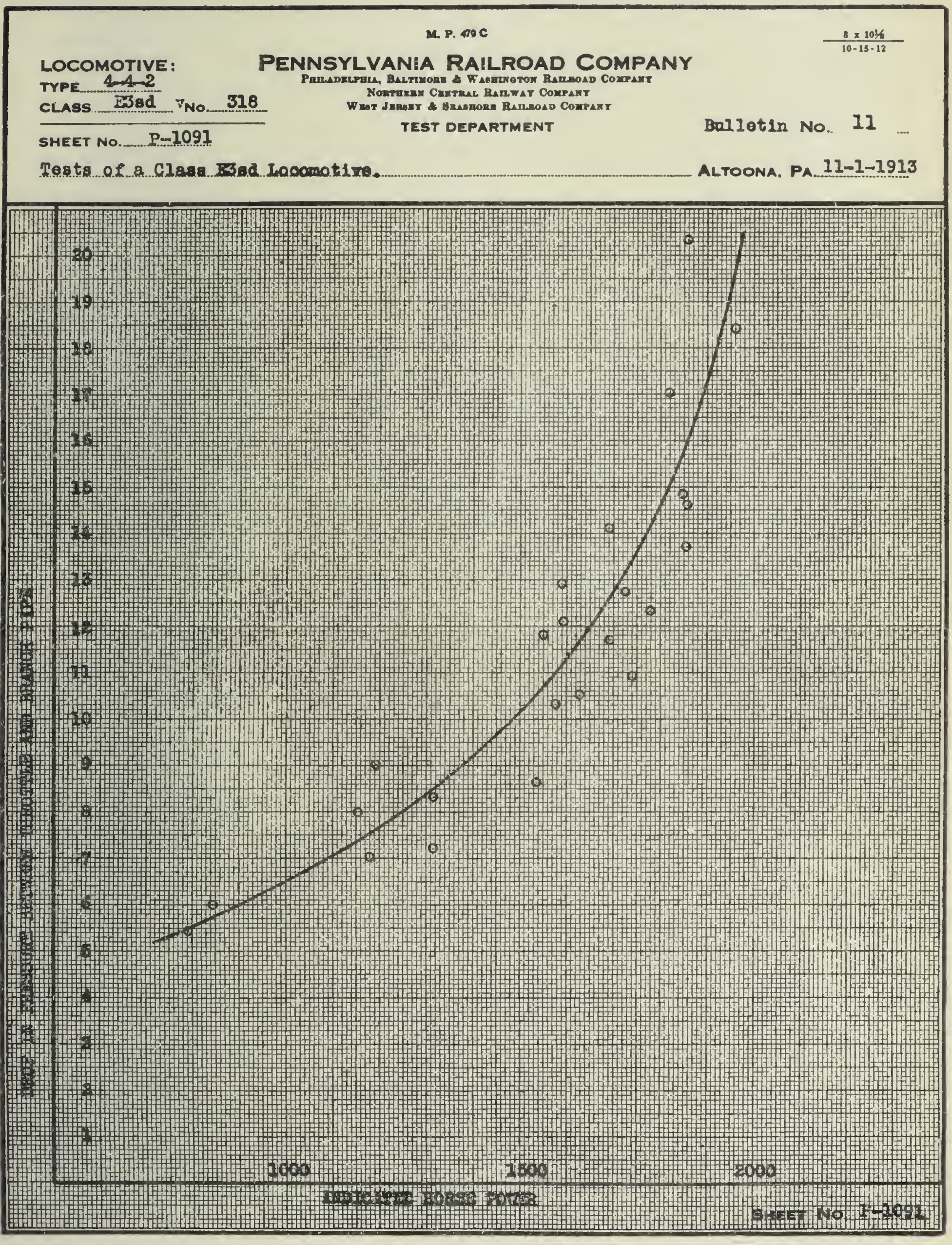

Fig. 35.

DROP IN PRESSURE THROUGH SUPERHEATER.

The drop in pressure increases with the power output of the locomotive, due to the increase in the volume of steam required to generate the increased power.

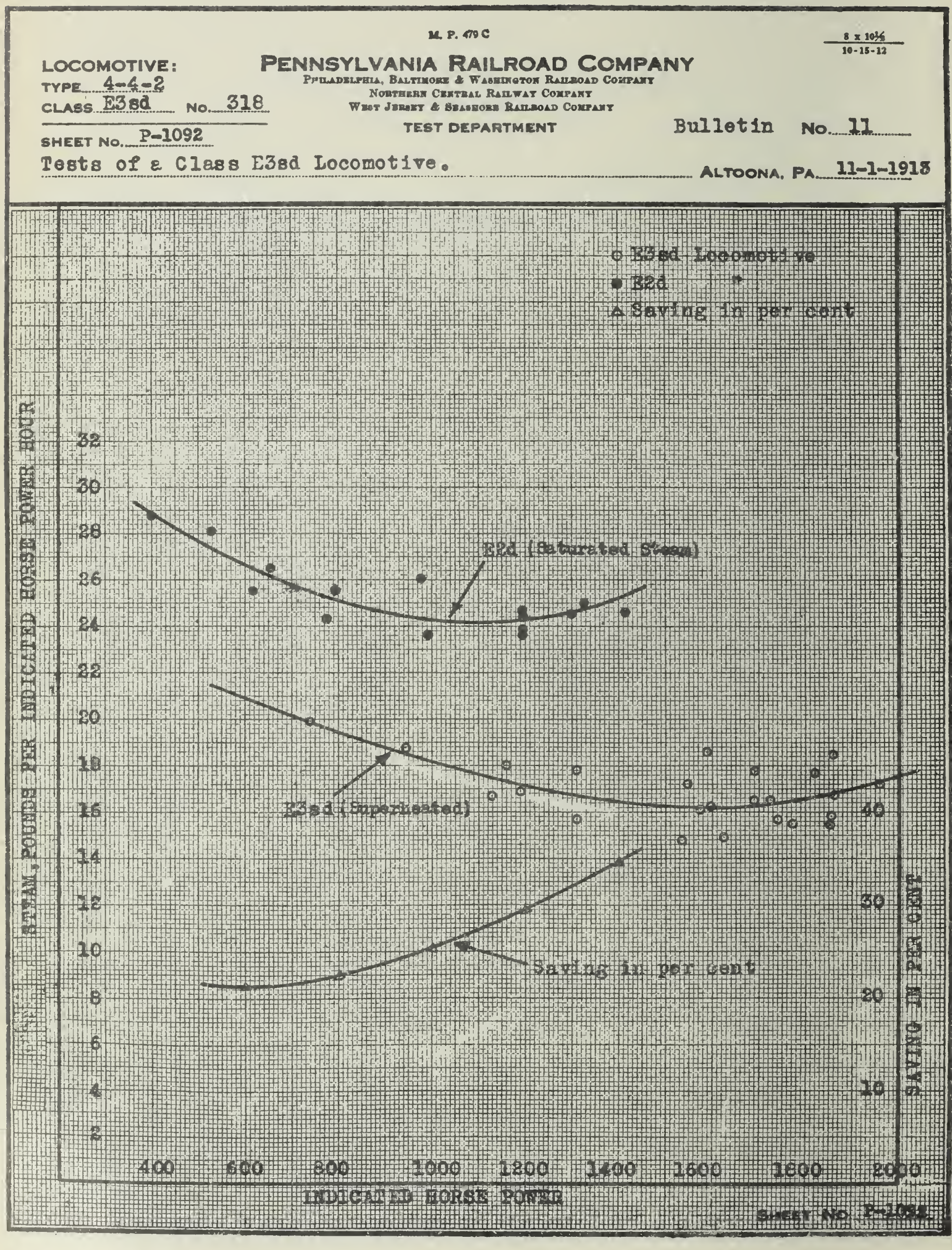

Fig. 36.

STEAM PER INDICATED HORSE-POWER HOUR AND INDICATED HORSE-POWER.

The saving in steam due to superheating is 21.4 to 34.5 per cent. at the maximum power output of the E2d saturated steam locomotive.

141. From the steam per hour curve (Fig. 37), the steam per indicated horse-power hour curve is plotted below in the same figure. It shows that the greatest steam economy should occur when the power output reaches 1550 i.h.p. The steam consumption at this point approximates 16.45 pounds per i.h.p. hour apparently increasing thereafter to 17.3 pounds per i.h.p. hour at the maximum output of the locomotive.

Superheat and Water Rate.

142. Table XV gives the draft in front of diaphragm in inches of water, the indicated horse-power, B.t.u. in the steam per indicated horse-power hour, superheated steam per indicated horse-power hour in pounds, dry coal per indicated horse-power hour in pounds and the superheat in the branch pipe. The table is arranged in order of the superheat in the branch pipe (column 230), from the minimum to maximum degree of superheat.

143. The B.t.u. in the steam per i.h.p. hour are plotted with the actual cut-offs in per cent. of stroke for corresponding tests in Fig. 38. Above the different points are printed the speed in r.p.m. The general trend of these curves for speeds up to and including 240 r.p.m. (56 m.p.h.), indicates that there was a gradual increase in the number of B.t.u. in the steam per i.h.p. hour as the per cent. of cut-off was increased. Above the speed of 240 r.p.m. the heat in the steam increased more rapidly. This should be expected as for a given water rate, the superheat should increase with an increase in cut-off or the power output of the locomotive.

Least Back Pressure.

144. The least back pressure for the E3sd locomotive gradually increased with the indicated horse-power up to 1600 i.h.p. Above that indicated horse-power it increased rapidly until the maximum power of the locomotive was reached. This is brought out in Fig. 39, where the least back pressure is plotted against the i.h.p. The least back pressure in the cylinders ranged from 1.9 pounds at the minimum i.h.p. to 11.8 pounds at the maximum power developed by the locomotive.

145. On this diagram is also graphically shown the relation existing between the indicated horse-power and the least back pressure in the cylinders of an E2d saturated steam locomotive. This curve is plotted from the results of a number of tests made on an E2d locomotive No. 3162.

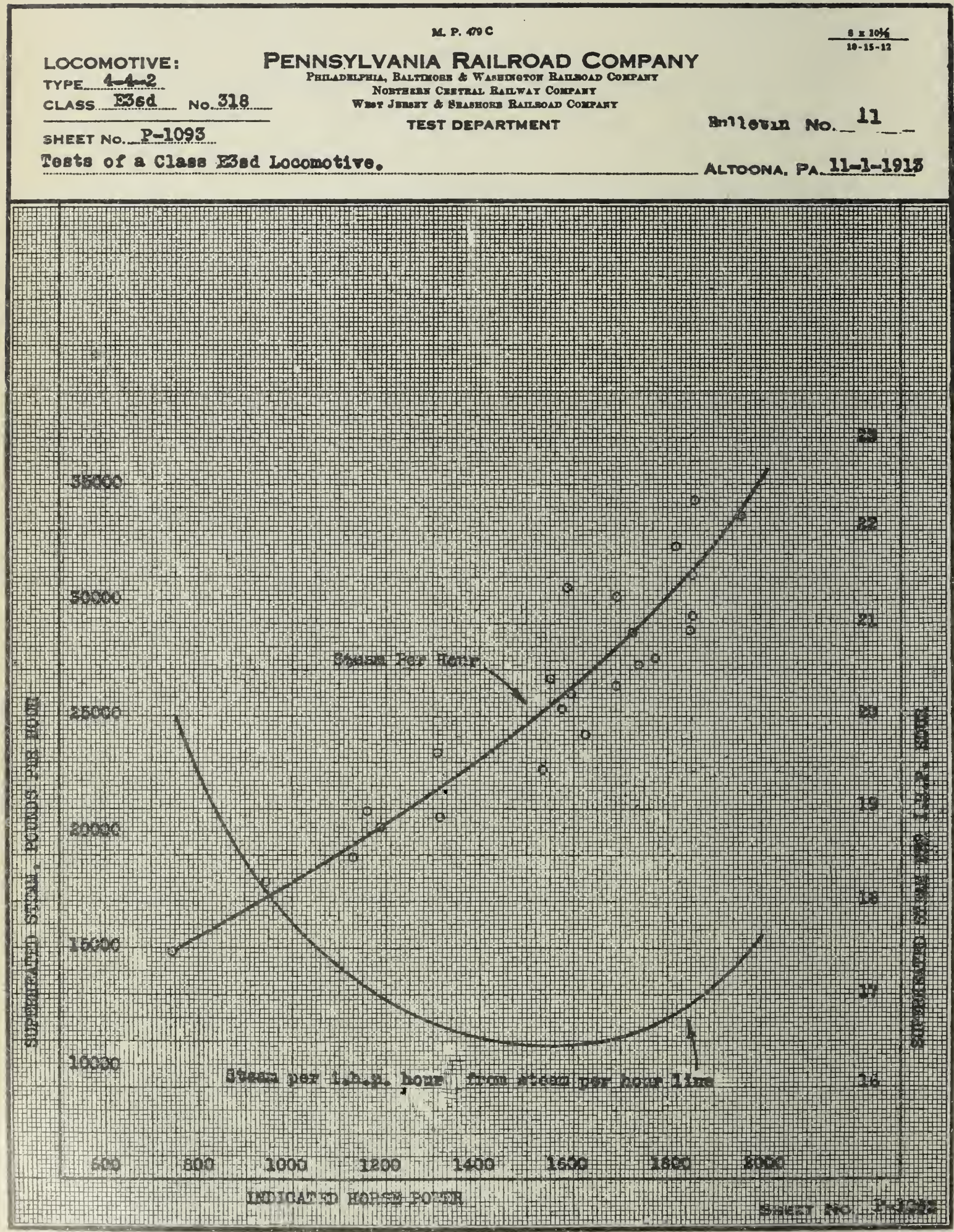

Fig. 37.

STEAM CONSUMPTION AND INDICATED HORSE-POWER.

The steam supplied to the engines and the indicated horse-power developed form the steam per hour curve. The steam per indicated horse-power hour curve is calculated from the above curve.

M. P. 479—A

351J 1-24 13
8 x 10½

LOCOMOTIVE:
TYPE 4-4-2
CLASS E3sd No. 318

PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

TEST DEPARTMENT

Bulletin No. 11

SHEET No. P-1094

Tests of a Class E3sd Locomotive. ALTOONA, PA. 11-1-1913

SUPERHEAT AND WATER RATE.

Test No.	Test Designa-tion	Draft Front of Diaphragm Inches of Water	Indicated Horse power	B.t.u. in Steam per Indicated Horse power Hour	Superheated Steam per Indicated Horse power Hour, pounds	Dry Coal Per Indicated Horsepower Hour, Pounds	Superheat in Branch Pipe
		222	379		381	380	230
3111	120-20-F	3.3	746.87	25236	19.91	2.28	118.15
3112	120-30-F	4.4	945.11	24140	18.86	2.37	138.70
3113	160-35-F	7.2	1313.80	22977	17.83	2.25	161.69
3114	160-45-F	10.9	1588.20	24130	18.62	3.08	175.07
3115	200-35-F	9.3	1548.90	22247	17.20	2.61	179.26
3137	120-40-F	5.7	1161.4	23536	18.01	2.53	192.56
3109	240-45-F	13.7	1861.8	24052	18.46	3.06	193.44
3136	200-20-F	4.6	1129.14	22028	16.74	2.17	195.44
3121	160-30-F	5.9	1193.9	22189	16.96	2.12	199.39
3126	320-20-F	8.0	1624.03	19560	14.91	2.33	207.43
3117	240-20-F	6.0	1315.6	20605	15.68	2.07	208.44
3133	160-50-F	10.6	1691.6	23422	17.79	3.24	211.67
3116	240-35-F	9.9	1724.4	21752	16.55	2.55	213.96
3134	200-35-F	8.3	1596.1	21303	16.24	2.80	218.04
3142	360-25-F	9.8	1776.96	20411	15.50	2.89	220.83
3119	280-20-F	7.6	1534.2	19438	14.78	2.10	221.08
3128	320-25-F	9.3	1738.9	19684	15.69	2.36	221.40
3143	360-25-F	10.3	1852.95	20373	15.46	2.94	221.47
3125	280-35-F	11.3	1858.4	22079	16.71	2.65	226.80
3135	200-35-F	8.0	1574.8	21262	16.09	2.33	227.37
3122	280-30-F	10.3	1690.5	20548	16.55	2.55	227.38
3127	320-30-F	11.4	1854.7	20903	15.81	3.03	228.29
3124	200-45-F	12.3	1820.6	23520	15.77	3.02	232.32
3139	240-45-F	12.8	1958.50	22859	17.17	3.05	253.84

SHEET No. P-1094

Table XV.

SUPERHEAT AND WATER RATE.

The maximum superheat obtained is 253.8 degrees. The table is presented to show the effect of the superheat upon the coal and water rates.

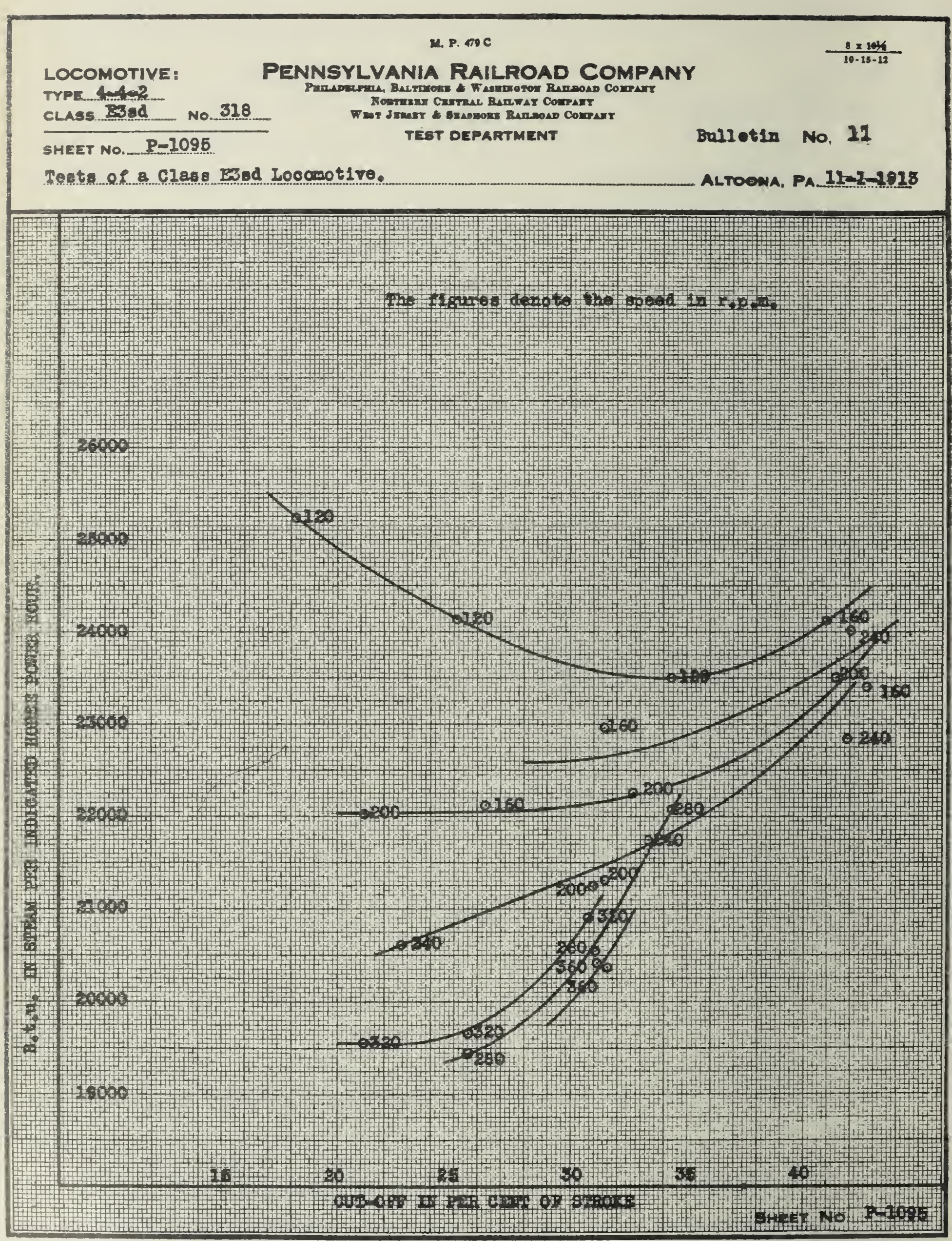

Fig. 38.

HEAT SUPPLIED AND CUT-OFF.

The heat supplied in the steam increases with the cut-off. This increase is gradual up to 240 revolutions per minute, or 56 miles per hour, after which it is more rapid.

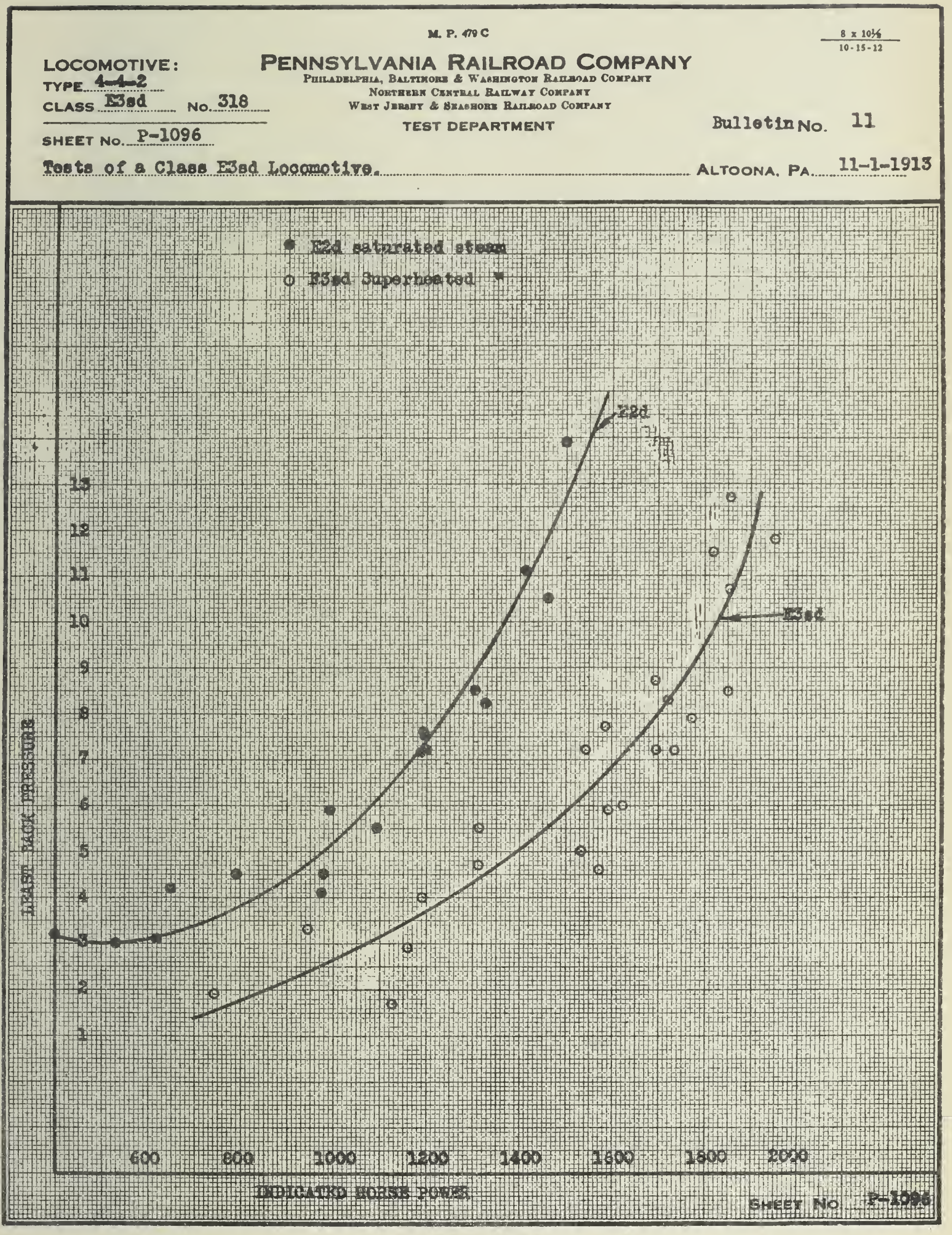

Fig. 39.

LEAST BACK PRESSURE AND INDICATED HORSE-POWER.

At corresponding indicated horse-powers the superheated steam locomotive exhausts with a least back pressure ranging from 42 per cent. to 50 per cent. of the least back pressure of the E2d saturated steam locomotive.

146. Comparing the curves for the saturated and superheater locomotives, it is seen that the curve representing the least back pressure for the saturated locomotive rises more abruptly as the power is increased.

147. It is also observed that for the same power output the superheated steam locomotive exhausted with a least back pressure ranging from 42.4 per cent. at 700 i.h.p. to 53.1 per cent. at 1400 i.h.p. (the maximum power attained for the saturated E2d locomotive) of the least back pressure obtained from the saturated steam locomotive.

148. A somewhat similar relation was shown between the E6 and E6s locomotives in Bulletin No. 21, Fig. 48. On the plot referred to, the curves are seen to parallel each other more closely, and the least back pressure for the E6s superheated steam locomotive was considerably less than for the E6 saturated locomotive.

149. The following table is presented to show a comparison between the least back pressure for the E2d and E6 saturated steam locomotives and the E3sd and the E6s superheated steam locomotives.

TABLE SHOWING COMPARISON BETWEEN THE LEAST BACK PRESSURE FOR THE E2D, E3SD, E6 AND E6S LOCOMOTIVES.

Indicated Horse-power Developed	Least Back Pressure		Difference in Pressure Favorable to E3sd Locomotive	Least Back Pressure		Difference in Pressure Favorable to E6s Locomotive	Difference in Pressure between E6s and E3sd Locomotives
	E2d	E3sd		E6	E6s		
700	3.3	1.4	1.9	....	0.70	....	0.70
800	3.8	1.8	2.0	....	0.70	....	1.10
900	4.4	2.2	2.2	....	0.75	....	1.45
1000	5.2	2.65	2.55	....	0.80	....	1.85
1100	6.2	3.2	3.0	....	0.95	....	2.25
1200	7.4	3.7	3.7	4.4	1.1	3.3	2.6
1300	8.9	4.3	4.6	4.7	1.4	3.3	2.9
1400	10.6	5.05	5.55	5.3	1.8	3.5	3.25
1500	12.6	5.9	6.7	6.2	2.3	3.9	3.6
1600	....	6.85	....	7.3	2.9	4.4	3.95
1700	....	8.0	....	8.5	3.7	4.8	4.3
1800	....	9.5	....	9.9	4.65	5.25	4.85
1900	....	11.8	....	....	5.8	....	6.0

150. When comparing this data it should be kept in mind that practically no difference exists between the E6 and the E6s locomotives, excepting the application of the superheater. While the E3sd locomotive, in addition to having a superheater has cylinders $1\frac{1}{2}$-inches larger in diameter than the cylinders of the E2d, and that the exhaust of the E3sd is furnishing draft for a boiler whose tubes are 9.4 per cent. longer than those of the E6s (see Par. 106).

151. Just what effect this has had on the least back pressure, is hard to discern in this instance. Comparing both classes of locomotives, there is seen the same tendency for their least back pressure to increase as the power output of the locomotive is increased, a condition that is reasonably anticipated.

152. At the same time the large difference existing between the least back pressures for the E3sd and E6s locomotives cannot fail to attract notice.

153. The cylinders are of like dimensions for both locomotives. The E6s locomotive has a larger boiler capacity.

154. A study of the designs for the E6s and E3sd locomotive cylinders reveals the most probable reason for the much greater least back pressure of the E3sd locomotive.

155. The exhaust passages in the E6s locomotive cylinders are direct with long radius bends as shown in Bulletin No. 21, Fig. 9, and their areas are sufficiently large. In the case of the E3sd locomotive (Fig. 8), the exhaust steam in its travel from the valve to the nozzle moves through a passage whose course changes at least four times. In some instances these turns are abrupt rather than of an easy radius similar to that of the bends in the passage of the E6s cylinders.

156. The design of the E6s locomotive cylinders, pertaining to the steam passages, their course and area, fulfills every requirement as shown by the performance of this locomotive No. 89 on the Test Plant. The results obtained from the tests on the E3sd locomotive, make it apparent that we might expect a somewhat better performance from this locomotive especially above an i.h.p. of 1500 if new cylinders were substituted with exhaust steam passages similar in design to those in the E6s locomotive cylinders.

157. Fig. 40, in which the least back pressure and the steam per indicated horse-power hour are plotted, indicates that the econ-

omy for any given cut-off increases with an increase in least back pressure under these test conditions and within their limits. It must not be assumed that back pressure in itself is advantageous. There is an unavoiadble increase in the back pressure with the increase in the volume of steam passed through the cylinder, but the increase in economy is due entirely to other causes.

158. This was similarly shown in Bulletin No. 21, Fig. 47 and Par. 120, for the E6s locomotive and in Bulletin No. 18, Fig. 51, for the Pacific type K2sa locomotive. As brought out in the Bulletin for the E6s locomotive, it is presumably necessary and probably pays to spend in back pressure for draft in proportion to the power and superheat developed, so as to realize the economy which results.

Draft.

159. The following Table XVI gives the actual cut-offs obtained from the indicator card, the speed in approximate miles per hour and the draft in front of diaphragm in inches of water for each of the tests.

Table XVI.

Actual Cut-off in Per Cent. of Stroke	Speed in Miles Per Hour						
	28	37	46	56	65	74	84
	Draft in front of diaphragm in inches of water						
18.3	3.3						
21.2			4.6			8.0	
22.8				6.0			
25.2	4.4						
25.7					7.6		
25.8						9.3	
26.4		5.9					
30.8						11.4	
31.1			8.0		10.3		
31.2							9.8
31.5		7.2	8.3				
31.6							10.3
32.7			9.3				
33.4				9.9			
34.4	5.7				11.3		
41.1		10.9					
41.5			12.3				
41.9				12.8			
42.1				13.7			
42.8		10.6					

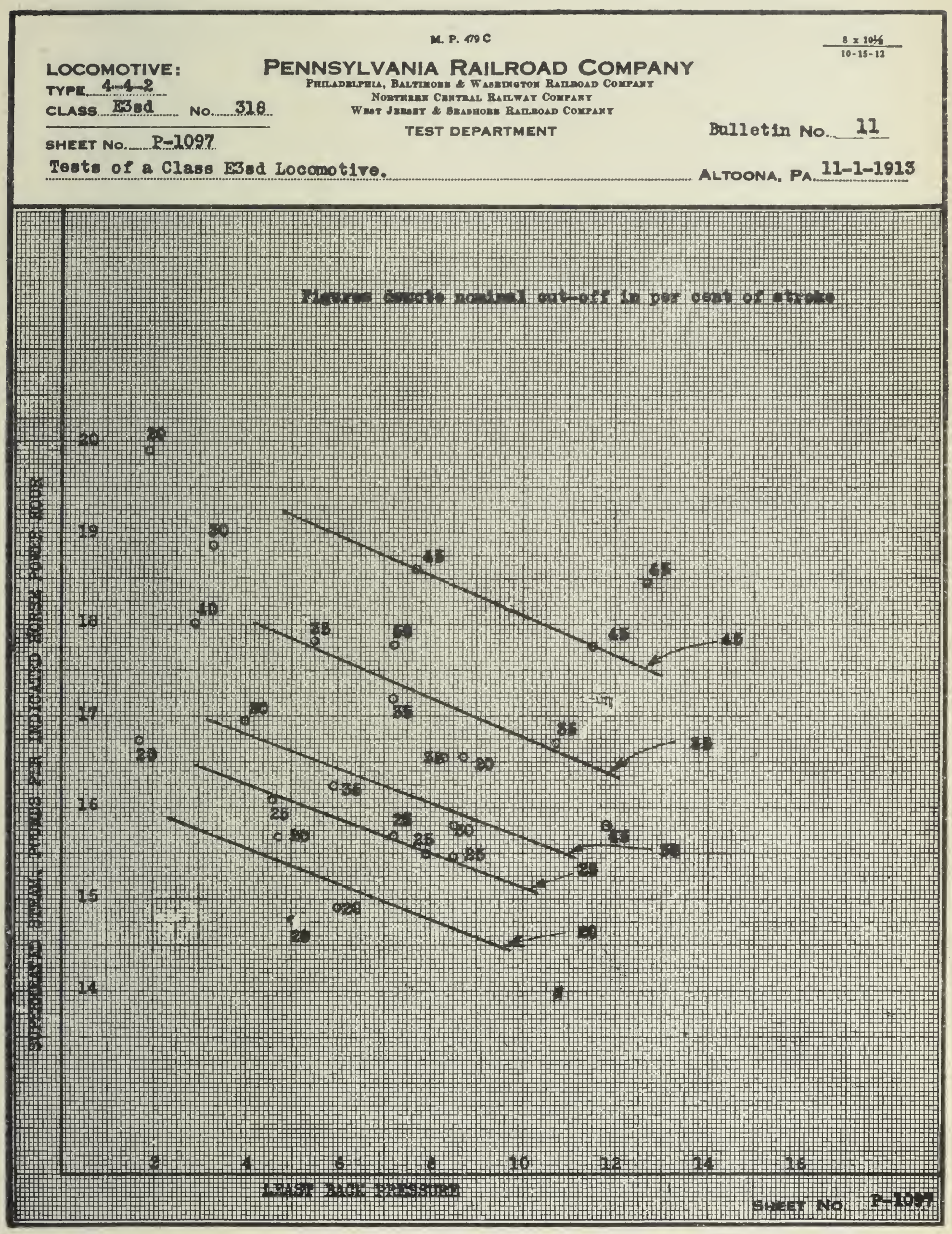

Fig. 40.

STEAM PER INDICATED HORSE-POWER AND LEAST BACK PRESSURE.

The steam supplied to the engines decreases with an increase in the least back pressure for any given cut-off.

160. A glance at the Table referred to shows the effect which may be had upon the draft brought about by the method of operating the locomotive with respect to speed and cut-off.

161. In Fig. 41 the draft in inches of water in front of diaphragm is plotted with the speed of the locomotive in miles per hour. Above each point may be seen the actual cut-off in per cent. of stroke, and curves are drawn through the points of approximately like cut-off.

162. These curves show the draft to increase directly with the speed of the locomotive, and the rate of increase for the drafts at similar cut-offs as the speed increases is approximately the same with the possible exception at the minimum cut-offs. This curve, it is noticeable, does not have such a steep slope as the other three.

Coal Rate.

163. Fig. 42 shows that the coal rate increased gradually with the indicated horse-power from 1700 pounds to 5700 pounds per hour. On the same plot is drawn another curve, the ordinates of which were calculated from the curve above. This lower curve shows that the average amount of coal consumed per i.h.p. hour increased gradually as the power of the locomotive increased. The dry coal fired per i.h.p. hour increased from 2.28 pounds to 3.05 pounds, while the indicated horse-power (column 379, Table XII) increased from minimum to maximum.

164. The dry coal in pounds per i.h.p. hour, and the indicated horse-powers are plotted in Fig. 43. The very gradual increase in the fuel consumption throughout the entire range of power output for this locomotive is apparent, and the corresponding rate of fuel consumption indicates a very good grate performance, all of which tends to show that the design of the firebox is well proportioned to the boiler requirements. It should be also remembered that the presence of the superheater and arch is responsible to a great extent for the economical fuel consumption of this locomotive.

165. Referring to Fig. 44, there is plotted at the lower portion of the diagram, the branch pipe pressure in pounds per square inch and the dry coal fired in pounds per indicated horse-power hour. It is apparent that the coal consumed per i.h.p. hour increased as

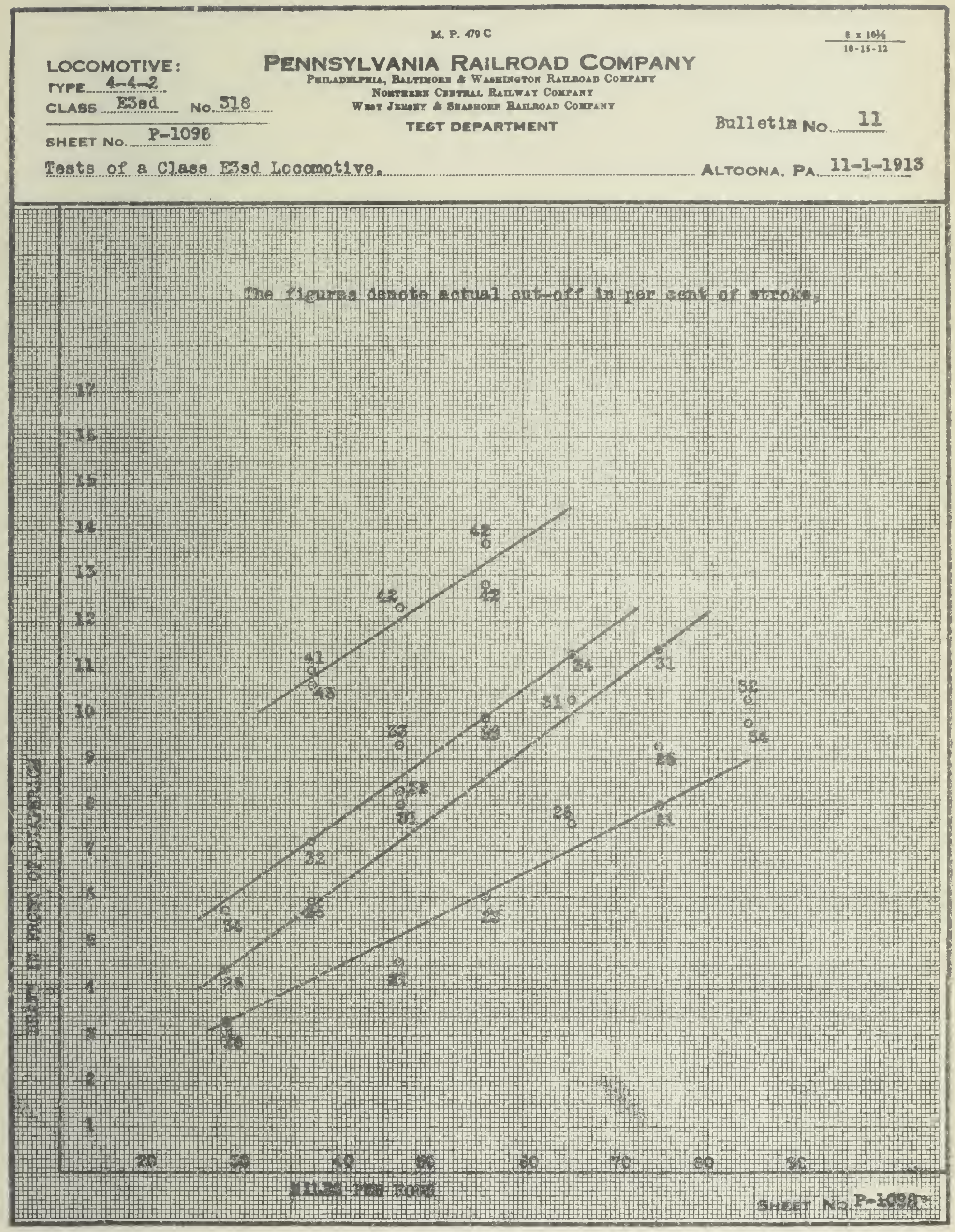

Fig. 41.

DRAFT IN FRONT OF DIAPHRAGM AND SPEED OF LOCOMOTIVE.

The draft increases directly with the speed of the locomotive at any given cut-off.

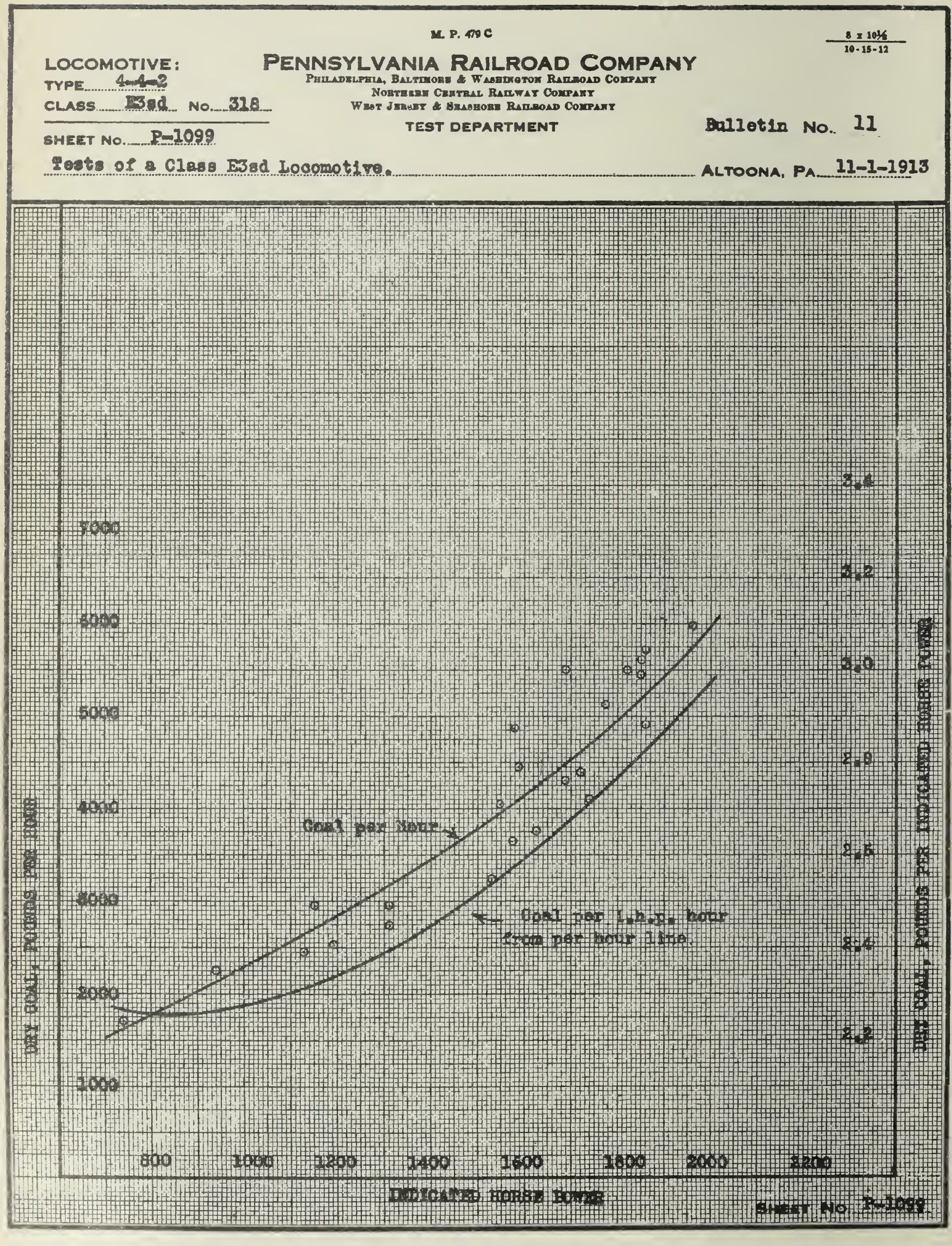

Fig. 42.

COAL PER HOUR AND INDICATED HORSE-POWER.

The coal per hour line shows the dry coal fired and the indicated horse-power developed. Below is given the coal per indicated horse-power hour curve calculated from the one above.

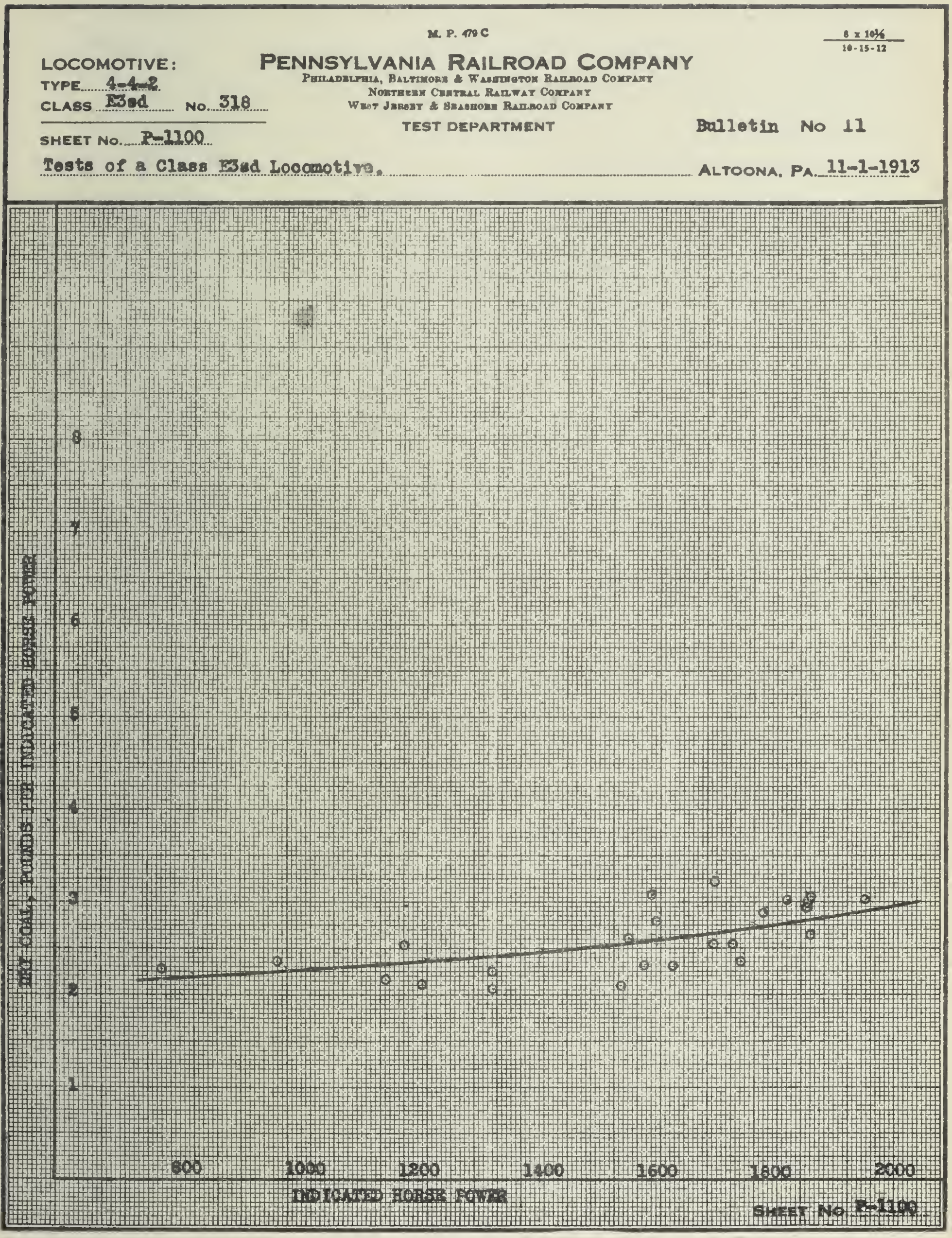

Fig. 43.
DRY COAL FIRED PER INDICATED HORSE-POWER HOUR AND HORSE-POWER.
The curve indicates a very gradual increase in fuel consumption throughout the range of power developed.

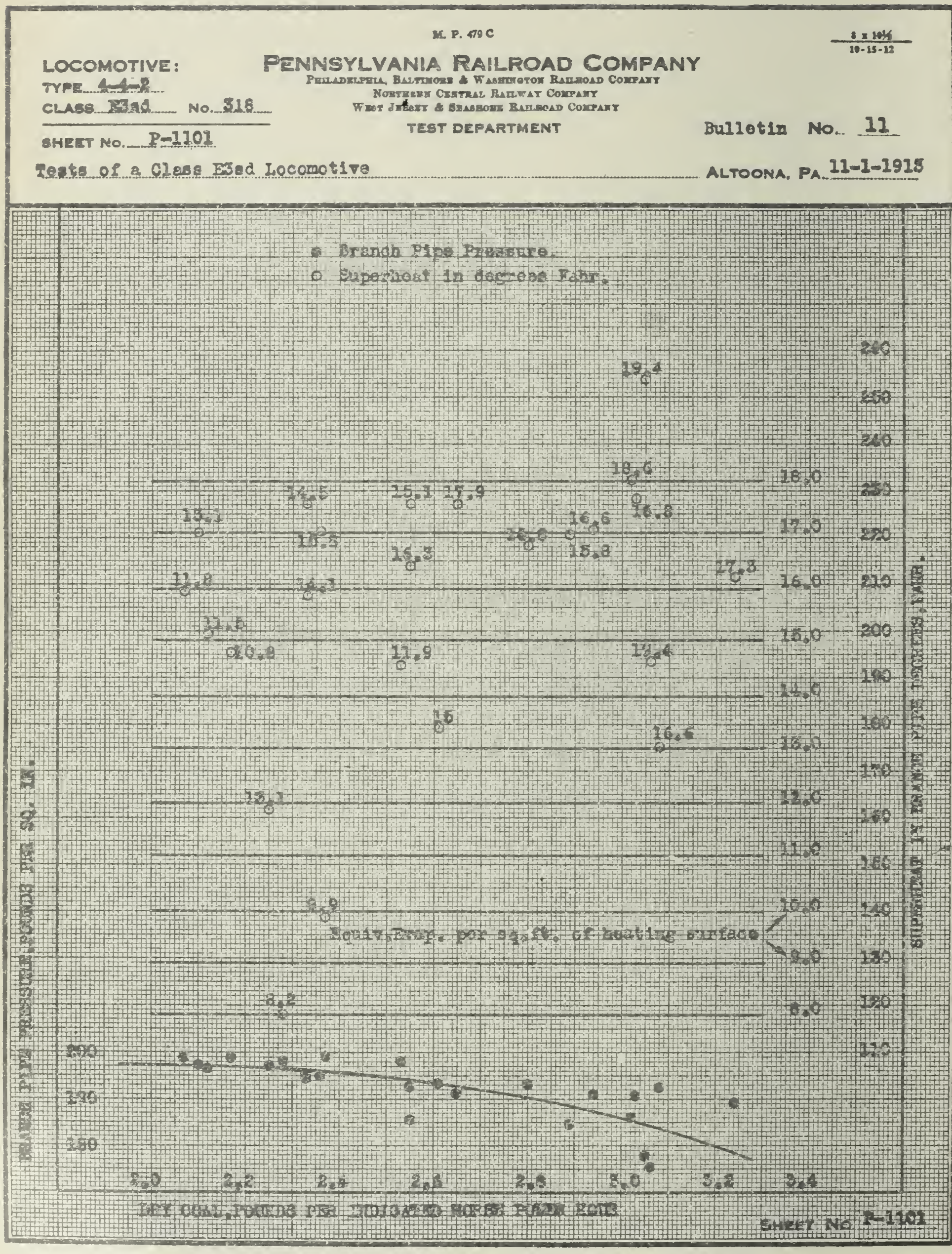

Fig. 44.

BRANCH PIPE PRESSURE, SUPERHEAT AND COAL RATE.

The superheat increases with the rate of evaporation, and the steam pressure in the branch pipe decreases as the rate of firing is increased.

the branch pipe pressure dropped. This increase in coal consumption was due to forcing the boiler to a higher rate of evaporation, and thus, since this drop takes place at the higher rates of evaporation it would appear that the cause is due either to the long passage for the steam through the superheater units or to some constricted point along its course (see Par. 91).

166. The drop in pressure is of importance since there can be no doubt that it materially lessens the maximum power output of the locomotive. Only after we have made some exhaustive tests on superheaters of this type of different lengths of tube and sizes, will we be able to draw a definite conclusion as to what limits we can safely approach in superheater size to minimize the drop in pressure at the branch pipe.

167. In the upper portion of this figure is shown the relation between the superheat in the branch pipe in degrees Fahrenheit, and the dry coal fired in pounds per i.h.p. hour. The value of the plot is to illustrate how the coal rate per i.h.p. hour is affected by a variation in the degrees of superheat at a given steam chest pressure. The relation shown is not as good as that shown similarly for the E6s locomotive (Bulletin 21, Fig. 64) or the K2sa locomotive (Bulletin 18, Fig. 59).

168. The points on this diagram are considerably more intermingled with respect to their corresponding rates of equivalent evaporation per square foot of heating surface printed immediately above.

169. Between the minimum and maximum rates of evaporation, namely 8 and 18, eleven lines are drawn at equal intervals, each representative of an evaporation rate which is marked at the end of the line.

170. The degree of superheat ranged from 120 to 230 degrees between the above limits. The former figure, 120 was reached when the equivalent evaporation per square foot of heating surface was 8.2 pounds, and the latter or 230 degrees at 18.6 pounds.

171. The conditions under which the locomotive was operated in respect to speed and cut-off are probably largely responsible for the variation of the several points from the lines as drawn. Nevertheless it is seen that the degree of superheat will increase with an increase in the evaporation rate at a fair rate of uniformity,

and a variation from the rule can only be explained in the operation of the locomotive under some varying condition.

172. As mentioned in Bulletin No. 18, Par. 143, this diagram brings out the point that the loss in efficiency, which is naturally expected on such a locomotive when forcing the boiler, is balanced to a great extent by the resulting increased superheat, for in consequence of this increased superheat the engines operate at a somewhat better water rate.

LOCOMOTIVE PERFORMANCE.

DYNAMOMETER RECORDS.

173. The application of a superheater to this Atlantic type locomotive had the effect of increasing the economy of the engines and the power of the locomotive as a unit. This has been emphasized in paragraphs 9 and 10 in the conclusions of Bulletin No. 21, describing the tests of class E6s Atlantic type locomotive, and in the following discussion comparison is similarly made between the E3sd superheater and E2d saturated steam locomotives. The economy in fuel and water, together with the increased power due to the application of a superheater and larger cylinders, is worthy of attention.

174. It is unfortunate that many of the tests made with the E2d locomotive were very short in duration. For this reason we are unable to show elaborate comparisons pertaining to the consumption of fuel. However, such facts as are mentioned may be considered representative for this class of locomotive, and serve to bring out some interesting information.

175. It is probable that the future usefulness of this type of locomotive may be increased to a considerable extent, since their conversion to superheater locomotives. With this in mind, the dynamometer records offer an interesting study. By an analysis of the data offered in the following pages, a fair idea may be had of the further possibilities of usefulness of the class E3sd locomotive from an operating standpoint, as well as its potency for an increase in power on a track structure limiting increase in wheel loads.

GRATE PERFORMANCE AND DYNAMOMETER HORSE-POWER.

176. Table XVII, arranged according to the increase in the dynamometer horse-power developed, may be frequently referred to in the following discussion. It contains the test number, the speed in r.p.m., the nominal cut-off, duration of test in minutes, drawbar pull in pounds, dynamometer horse-power, dry coal per dynamometer horse-power hour in pounds, superheated steam per dynamometer horse-power hour in pounds, B.t.u. in the steam per drawbar horse-power hour and the thermal efficiency of the locomotive in per cent.

M. P. 479—A

8 x 10½
851 4-29-13

LOCOMOTIVE:
TYPE 4-4-2
CLASS E3sd No. 318

SHEET NO. P-1102

PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

TEST DEPARTMENT

Bueltin No. 11

Tests of a Class E3sd Locomotive. ALTOONA, PA. 11-1-1913

DRAWBAR HORSE POWER

Test No.	Test Designation	Duration of Test Mins.	Draw-bar Pull in Pounds	Dynamometer or Drawbar Horsepower	Dry Coal per Dynamometer Horsepower Hour	Superheated Steam per Dynamometer Horsepower Hour, Pounds	B.t.u. in Steam per Drawbar Horsepower Hour	Thermal Efficiency of Locomo. Percent
			265	383	384	385		399
3111	120-20-F	120	6678	498.7	3.42	29.82	37815	5.15
3112	120-30-F	120	9516	710.6	3.15	25.09	32076	5.59
3126	320-20-F	60	4620	920.0	4.11	26.31	34537	4.34
3136	200-20-F	120	7407	921.9	2.66	20.50	26823	6.56
3117	240-20-F	120	6409	957.2	2.85	21.55	28343	6.26
3119	280-20-F	90	5503	958.9	3.36	23.65	31107	5.31
3137	120-40-F	120	13136	980.9	3.00	21.33	27846	5.82
3121	160-30-F	120	10057	1001.4	2.52	20.22	26461	7.08
3113	160-35-F	120	11025	1097.7	2.69	21.34	27526	6.55
3127	320-30-F	60	5951	1185.1	4.74	24.74	32711	3.68
3128	320-25-F	60	5965	1187.8	3.46	22.97	30017	5.04
3143	360-25-F	30	5316	1190.9	4.57	24.06	31734	3.83
3122	280-30-F	60	7090	1235.4	3.49	21.30	28137	5.11
3115	200-35-F	120	9953	1238.8	3.26	21.51	27853	5.41
3142	360-25-F	30	5676	1271.6	4.04	21.66	28544	4.32
3134	200-35-F	60	10628	1322.8	3.38	19.59	25708	5.16
3116	240-35-F	90	8965	1338.9	3.28	21.32	28047	5.44
3135	200-35-F	60	10763	1339.6	2.73	18.92	25017	6.39
3114	160-45-F	90	13565	1350.6	3.62	21.89	28379	4.87
3125	280-35-F	60	8034	1399.9	3.51	22.18	29316	5.08
3133	160-50-F	60	15114	1504.9	3.66	20.06	26352	4.77
3109	240-45-F	60	10274	1534.4	3.72	22.39	29176	4.74
3124	200-45-F	90	12357	1538.0	3.57	21.04	27844	5.00
3139	240-45-F	60	10536	1573.6	3.80	21.37	28358	4.59

SHEET NO. P-1102

Table XVII.

DRAWBAR HORSE-POWER.

This locomotive developed a drawbar pull of 5676 pounds at 84 miles per hour, a maximum dynamometer horse-power of 1573.6 at 56 miles per hour and a thermal efficiency ranging from 4.34 to 7.08 per cent.

177. The dynamometer horse-power obtained with the E3sd locomotive ranged from a minimum of 498.7 to a maximum of 1573.6 horse-power. During the increase in the power of the locomotive, the coal rate per hour per square foot of grate increased from 31.19 to 109.27.

178. In Fig. 45, which shows the dynamometer horse-power, boiler efficiency and rates of firing in pounds per square foot of grate, it will be observed that there is a sharp rise in dynamometer horse-power as the rates of firing increase up to about 60 pounds per square foot of grate. At higher rates of combustion the horse-power shows a uniform increase up to a maximum of about 1600.

179. On the same diagram, the efficiency of the boiler is shown as a straight line. As the power and combustion rates were increased, the boiler efficiency decreased from 77.2 per cent. to 51.3 per cent.

180. Now, referring to Fig. 46, there is shown graphically the effect of speed upon the combustion rate per dynamometer horse-power hour. As the speed increased to 60 miles per hour the increase in the coal rate was slight, but above this speed the rate of firing increased rapidly. This indicates the E3sd locomotive to be more economical in burning fuel when running at speeds under 60 m.p.h. The uniformity in the coal rate per dynamometer horse-power up to 60 m.p.h. is characteristic of superheater locomotives, and is not so apparent with the saturated steam locomotive; a typical instance of this is shown for the E6 Atlantic type locomotive. The curve for the E6 locomotive is plotted above on the same figure and it will be observed that at 45 m.p.h. there is an abrupt change in the rate of fuel consumption, and it rapidly increases with the increase in the speed. The E2a locomotive, Atlantic type, using saturated steam and fired with a different grade of coal, shows the same tendency, although not to such a marked degree (see Bulletin No. 5).

Steam Consumption and Its Relation to Piston Speed.

181. The steam consumption per indicated horse-power hour is plotted against the speed of the piston in feet per minute in

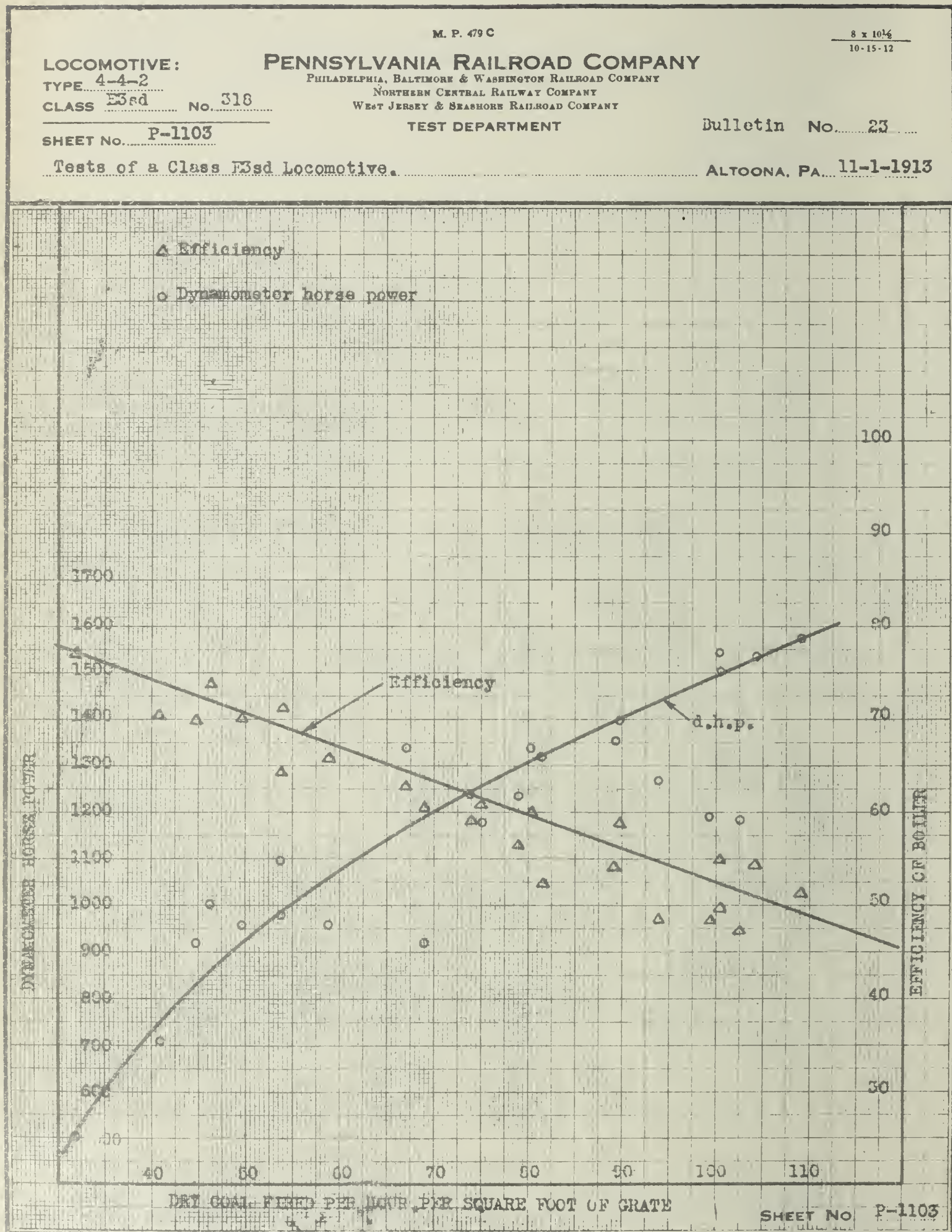

Fig. 45.

DYNAMOMETER HORSE-POWER AND COAL FIRED PER SQUARE FOOT OF GRATE.

While the increase in the rate of firing is gradual up to 1200 dynamometer horse-power, it shows a greater degree of uniformity above this horse-power. The boiler efficiency decreases directly with an increase in the rate of combustion.

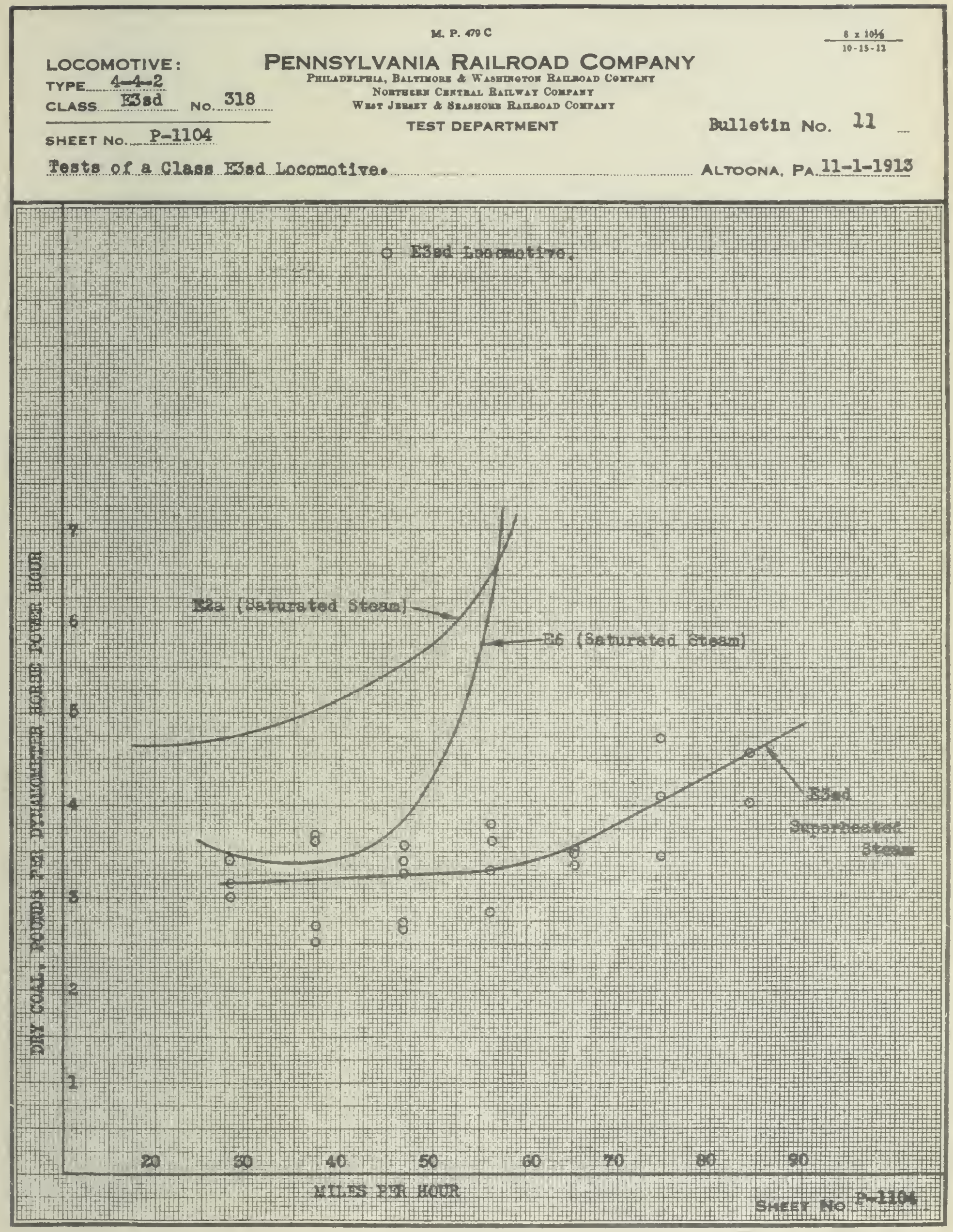

Fig. 46.

DRY COAL PER DYNAMOMETER HORSE-POWER HOUR AND SPEED OF LOCOMOTIVE.

The greater uniformity in the coal rate per dynamometer horse-power hour is characteristic of the superheated steam locomotive.

Fig. 47. This diagram contains a number of curves representing similarly other classes of locomotives that have been on the Test Plant. These locomotives have all been previously reported and are here given for the purpose of comparison with the E3sd locomotive.

182. It is of interest to note that at piston speeds up to 1400 feet per minute, the performance of the E3sd locomotive outstrips all other locomotives, with the exception of the Hannover Compound carrying a low degree of superheat.

183. The K2sa simple Pacific type locomotive with superheater, slightly exceeds the economical performance of the E3sd locomotive at speeds above 1400 feet per minute.

184. The diagram shows the exceptionally low water rate of the E3sd locomotive as compared with the other locomotives at a high rate of speed, namely, 15.5 pounds per i.h.p. hour at a piston speed of 1600 feet per minute and 19.2 pounds per i.h.p. hour at 500 feet per minute. At 1385 feet per minute the water rates for the K2sa and E3sd are alike, 15.6 pounds per i.h.p. hour. The water rate for the E3sd is less than that for the E6s throughout the whole range of piston speed.

185. The similarity of the curves for the E3sd and E6s locomotives will be noticed. The cylinders on both locomotives are 22 inches by 26 inches, and the fact that they are of like dimensions no doubt accounts for the similar decrease in the water rate for the two locomotives, especially is this true at high speeds.

186. Likewise is apparent the similarity in the shape of the curves for the E3sd superheater locomotive, and the E2a simple saturated steam locomotive at speeds below 1000 feet per minute. These locomotives are similar in all respects, with the exception of valves and valve gears. The E2a locomotive had the Wilson slide valve and the Stephenson valve gear.

187. Comparing the curve for the E3sd superheater locomotive with that representing the performance of the E2d saturated steam locomotive on this diagram, the benefit to be derived by using a high degree of superheat in preference to saturated steam is at once apparent. By adding a superheater to this locomotive we have affected an economy in its water rate, based on piston speed, of approximately 25 per cent. Both locomotives were tested under similar conditions and were fired with the same grade of coal.

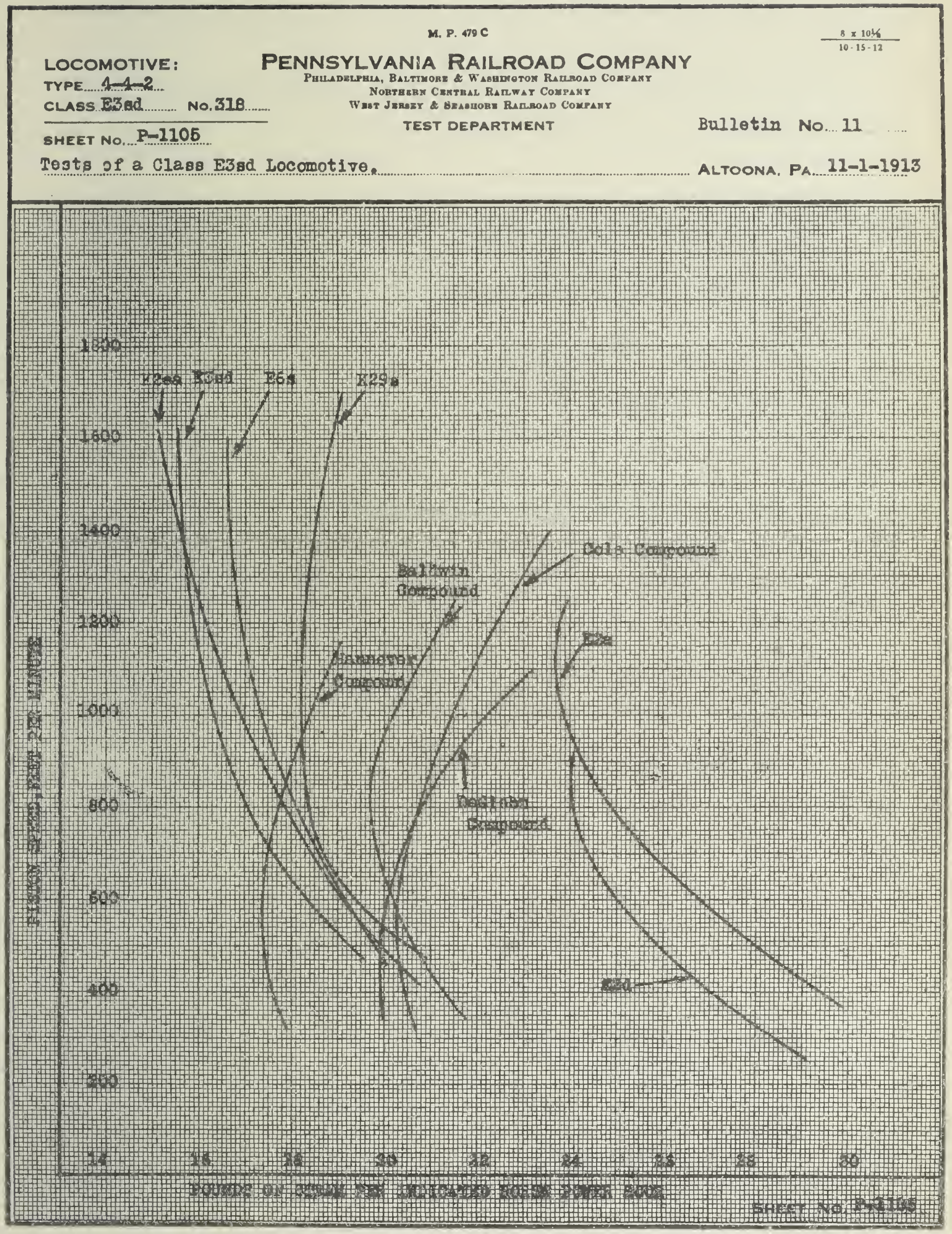

Fig. 47.

PISTON SPEED AND WATER RATE.

Between piston speeds of 700 and 1400 feet per minute the E3sd simple superheated steam locomotive outstrips all other locomotives previously tested on the test plant. The simple superheated steam locomotives (K2sa, E3sd, E6s and K29s) at piston speeds above 950 feet per minute show better results than the other locomotives.

188. Again attention may be called to the economy that may be derived from the use of highly superheated steam in a simple engine. The curves in the diagram (Fig. 47), show conclusively the economy to be obtained above that received from compounding or using a low degree of superheat in a compound locomotive.

189. Fig. 48 is presented to show the relation between the cut-off in per cent. of stroke and the superheated steam in pounds per indicated horse-power hour.

190. Fig. 49 illustrates graphically the relation between the indicated horse-power developed and the cut-off at the different speeds the locomotive was operated. These speeds in r.p.m. are printed above their respective points.

Maximum Power of Locomotive.

191. The drawbar pull that the E3sd locomotive is able to develop and sustain, is worked up in a manner previously described in Bulletin No. 5, "Tests of an E2a Locomotive," pages 27 to 32 inclusive. This method has been used in all tests previously reported. A portion of the necessary data is obtained from Figs. 48 and 49, given in this Bulletin.

192. The relation between the speed and drawbar pull is shown graphically in Fig. 50. The dotted lines indicate the drawbar pull, which may be expected for cut-offs ranging from 20 to 50 per cent.

193. The maximum drawbar pull, represented by the solid line or curve, at a speed of 38.5 miles per hour is 15,000 pounds, when the cut-off is 50 per cent. of the stroke. In other words, at 50 per cent. cut-off the capacity of the boiler will not be overtaxed providing the locomotive is operated at a speed of 38.5 m.p.h. or less. On the other hand, if we exceed this speed, the cut-off must be reduced to less than 50 per cent.

194. The following table (XVIII) illustrates the maximum calculated drawbar pull for this locomotive (E3sd) for speeds ranging between 37 and 75 miles per hour:

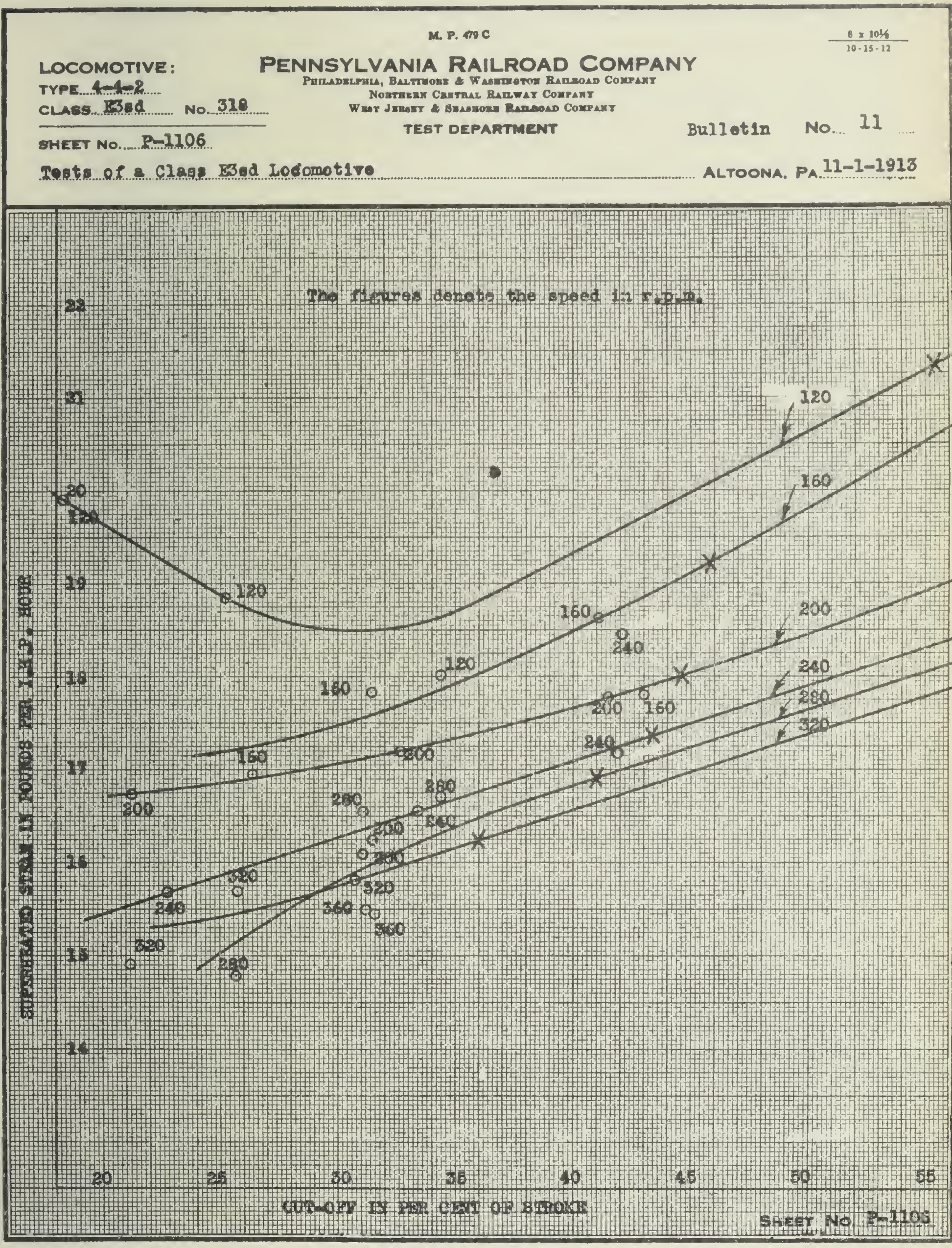

Fig. 48.

STEAM PER INDICATED HORSE-POWER HOUR AND CUT-OFF.

This figure is used in calculating the maximum drawbar pull. The "X" on each speed line indicates the critical cut-off for that speed.

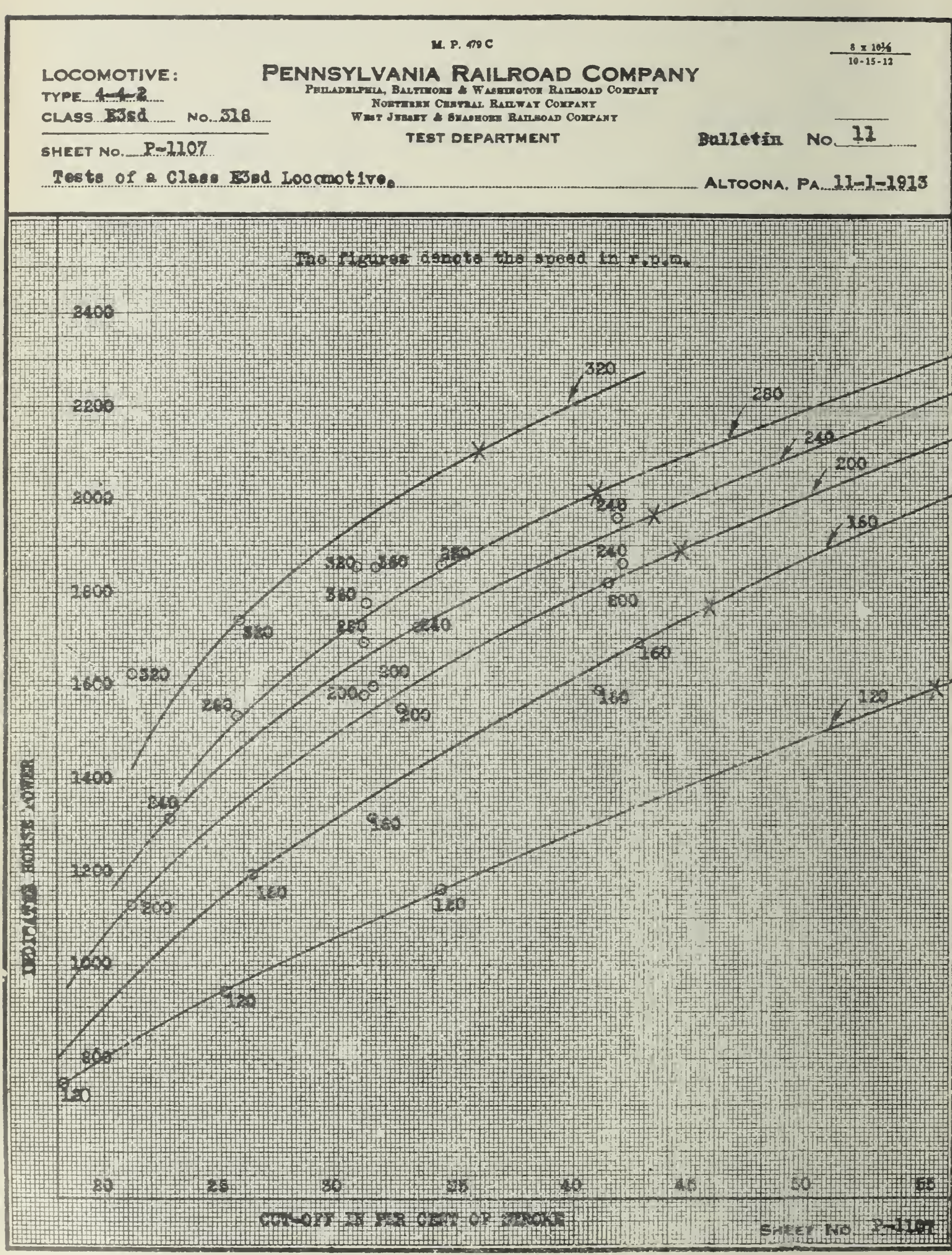

Fig. 49.

INDICATED HORSE-POWER AND CUT-OFF.

This figure, together with Fig. 48, is used in calculating the maximum drawbar pull. The "X" on each speed line indicates the critical cut-off for that speed.

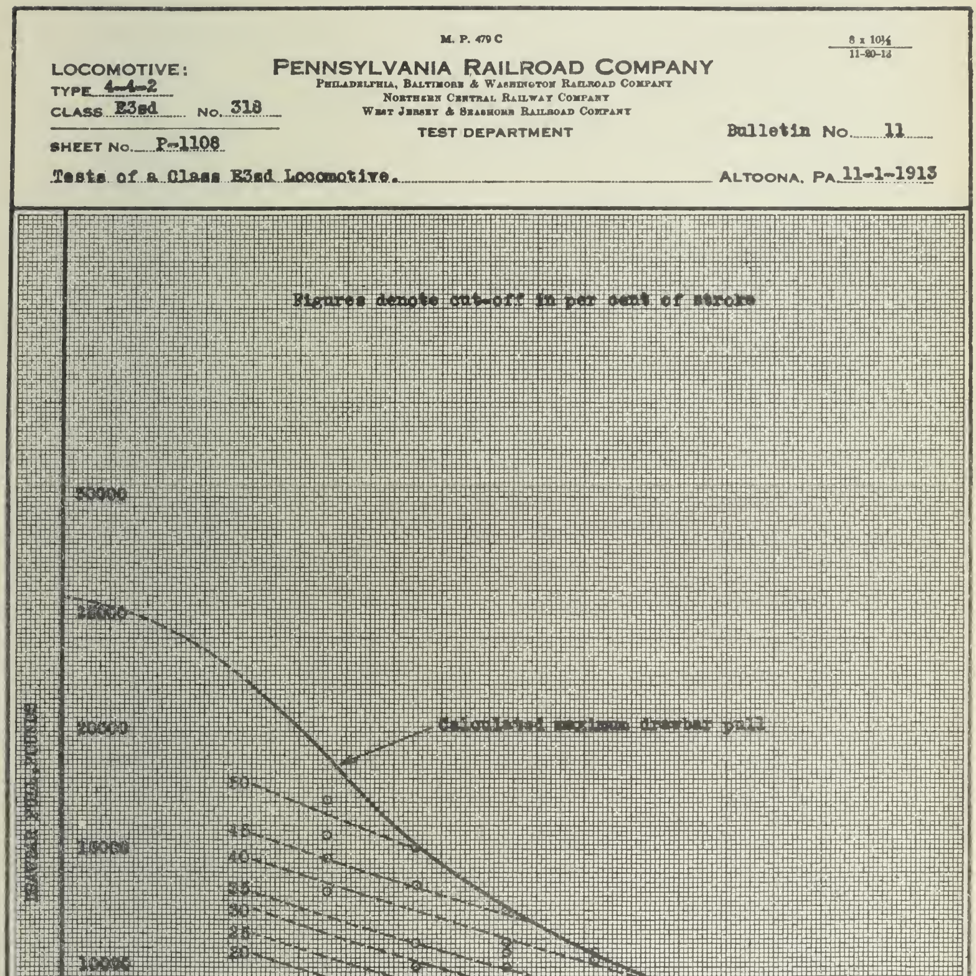

Fig. 50.
DRAWBAR PULL AND SPEED OF LOCOMOTIVE.
This diagram shows the actual and calculated drawbar pull at speeds from 28 to 84 miles per hour.

TABLE XVIII.

Atlantic Type Locomotive, Class E3sd, No. 318.

Speed in r.p.m.	Speed in m.p.h.	Cut-off in Per Cent. of Stroke	Steam per i.h.p. hour Pounds	Maximum Cylinder Horse Power	Total Steam Per Hour Pounds	Average Machine Friction in d.h.p. Pounds	Estimated Maximum Drawbar Pull Pounds	Actual Maximum Drawbar Pull Pounds
1	2	3	4	5	6	7	8	9
160	37.34	45.8	19.22	1770	34019	2105	15235	16300
200	46.68	44.6	18.00	1890	34020	2103	12642	13300
240	56.02	43.4	17.35	1965	34092	2438	10613	10700
280	65.35	41.0	16.90	2015	34053	2848	9022	8500
320	74.69	36.0	16.22	2100	34020	3222	8003	6900

195. The maximum evaporation of this locomotive was approximately 34,000 pounds of water per hour, which was maintained for one hour's run, as shown in test 3139, Table XIII.

196. Referring to Figs. 48 and 49, the critical cut-off is designated by a cross-mark on each of the several curves. The product of the steam consumption (Fig. 48) and the indicated horsepower (Fig. 49) for each critical cut-off will approximate 34,000 pounds (the maximum steam capacity) shown in column 6 of Table XVIII. The figures under columns 3, 4 and 5 were likewise obtained from Figs. 48 and 49.

197. Figures under column 7 represent the average frictional drawbar pull in pounds, assumed as the average for the whole series of tests given in Table XIX, column 397. This frictional loss amounts to 2541 pounds.

Column 8, the estimated maximum drawbar pull in pounds for each speed, is obtained by the formula:

$$P = \frac{W \times 375}{S} - F.$$

Where P = maximum drawbar pull in pounds.
W = maximum indicated horse-power.
S = speed in miles per hour.
F = average frictional drawbar pull.

198. Fig. 51 is presented to illustrate graphically the drawbar pull throughout the speed range of this locomotive. There is also plotted on this sheet the maximum drawbar pull for the E2d saturated locomotive. This saturated steam locomotive has cylinders $20\frac{1}{2}$ inches by 26 inches. Thus the E3sd and E2d are similar in nearly every respect with the exception that the E3sd is equipped with a superheater, an arch and larger cylinders, which account for its increased drawbar pull.

199. An analysis of the plot shows that by adding a superheater and larger cylinders to this E2d locomotive we have increased its drawbar pull approximately 38.8 per cent. at 50 miles per hour and 14.4 per cent. at a speed of 20 miles per hour above the drawbar pull obtained for the E2d locomotive. The curve for the drawbar pull of the E2d locomotive is representative of this type and class of saturated steam locomotive.

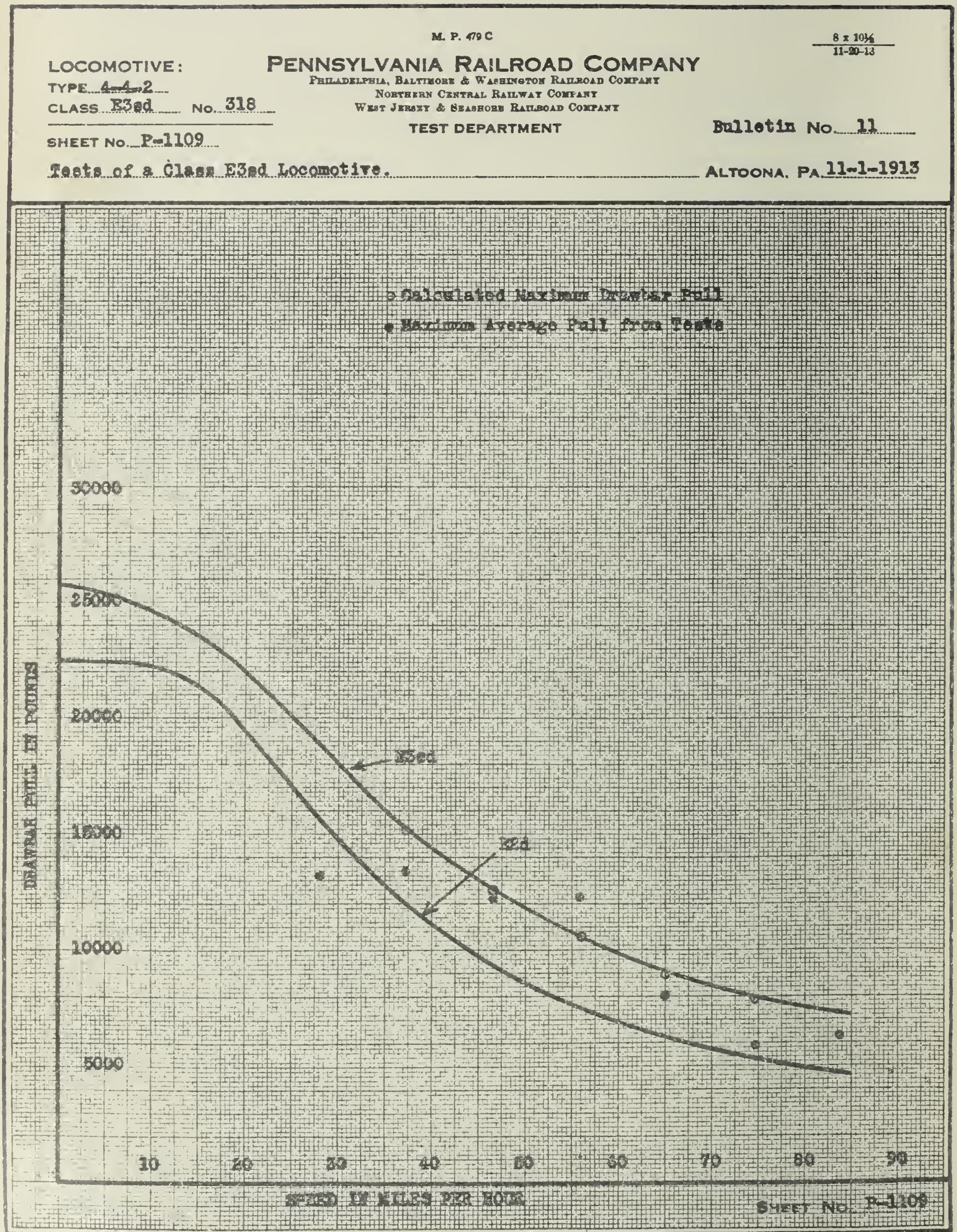

Fig. 51.

DRAWBAR PULL AND LOCOMOTIVE SPEED.

This diagram shows drawbar pulls for the E2d saturated steam locomotive as compared with the increased drawbar pulls obtained from the E3sd superheated steam locomotive.

Steam Consumption per Dynamometer Horse-Power Hour.

200. Fig. 52 shows the steam consumption per dynamometer horse-power hour, plotted with the speed in miles per hour, and shows the gradual increase in steam consumption as the speed of the locomotive is increased. The points all lie in a zone area as in the case of the E6s locomotive, shown in Fig. 66, Bulletin No. 21. The various points are marked according to their respective cut-offs. It may be observed that there is no definite relation between speed and cut-off.

201. Above on the same diagram is also graphically presented the steam consumption in pounds per dynamometer horse-power hour at various speeds for the E2d saturated steam locomotive.

202. The saving in the water rate per dynamometer horse-power hour for the superheater locomotive above that of the saturated steam locomotive is 34 per cent. at speeds ranging from 30 to 55 miles per hour.

Least Back Pressure.

203. The rapid increase in back pressure for the E3sd locomotive as the dynamometer horse-power is increased is shown in Fig. 53, varying from 1.7 to 12.7 pounds. The relation is very similar to that shown between the least back pressure and the indicated horse-power presented graphically in Fig. 39 of this Bulletin.

204. A comparison with the curve above on this diagram (Fig. 53) representing the E2d saturated steam locomotive similarly shows the greater increase in the least back pressure for the locomotive using saturated steam as its dynamometer horse-power is increased.

205. In this instance it will be observed that the increase in least back pressure for the E2d saturated steam locomotive ranges from 79 per cent. at 500 d.h.p. to 82 per cent. at 1150 d.h.p. above that obtained from the superheated steam locomotive.

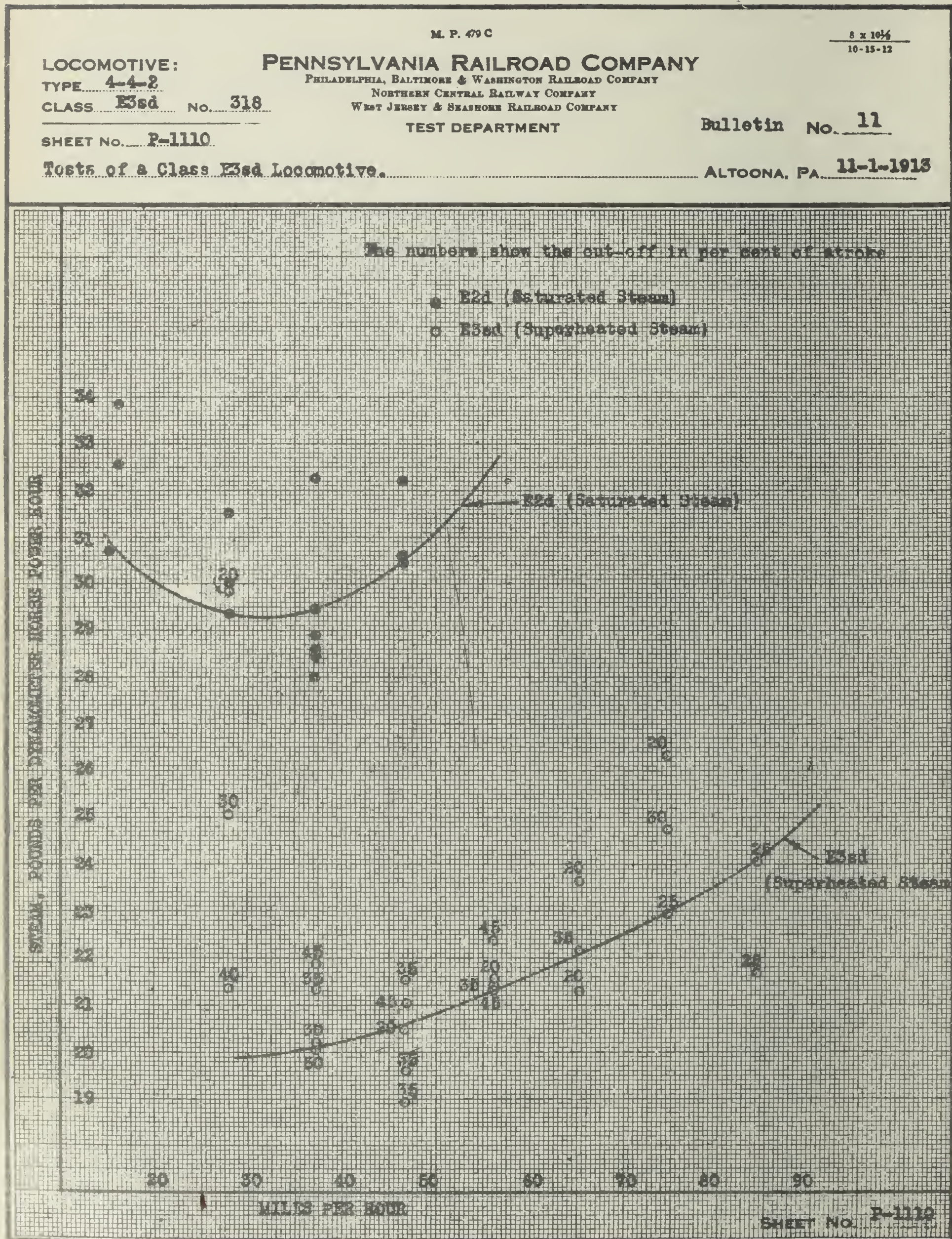

Fig. 52.

WATER RATE PER DYNAMOMETER HORSE-POWER HOUR AND SPEED.

The use of superheated steam on this E3sd locomotive effects a saving of 34 per cent. in steam for speeds ranging from 30 to 55 miles per hour.

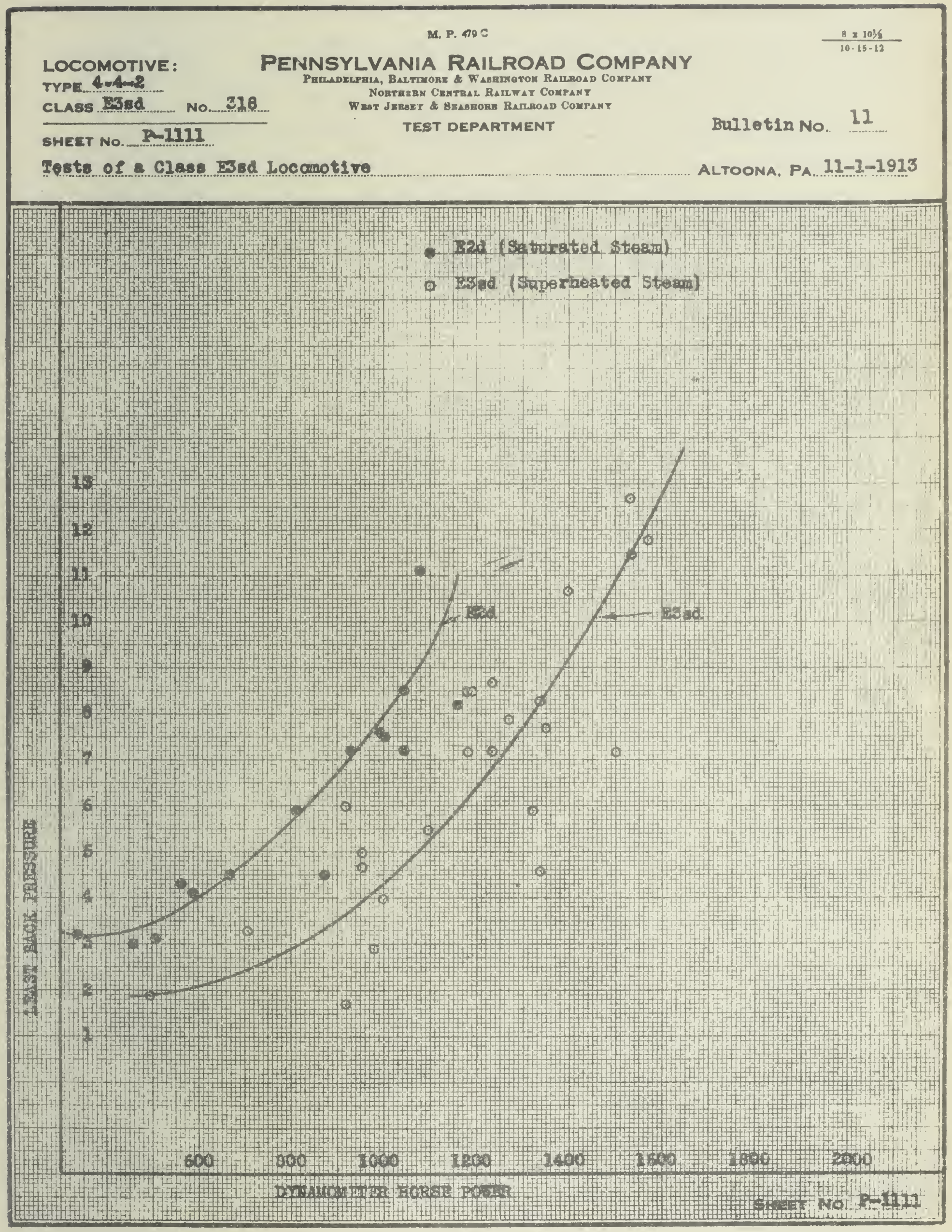

Fig. 53.

LEAST BACK PRESSURE AND DYNAMOMETER HORSE-POWER.

This diagram shows the greater increase in the least back pressure of an E2d locomotive using saturated steam, compared with the E3sd superheated steam locomotive throughout the entire range of dynamometer horse-power.

Machine Friction.

206. Under the heading "Machine Friction," there is given in Table XIX, together with the test number and test designation, the machine friction expressed in terms of horse-power, mean effective pressure in pounds per square inch, drawbar pull in pounds, steam to engines in pounds per hour, dry coal fired in pounds per hour and the machine efficiency in per cent. The table is arranged in order according to speed and cut-off. The cut-off at each speed is increased throughout each range of speed.

207. The machine friction causes approximately 3000 pounds loss in drawbar pull when at the lower speeds, but as the speed increases, it decreases to a minimum loss of 1665 pounds at 46.68 miles per hour, and as the speed increases from this point to 74.7 miles per hour the machine friction loss also increases to approximately 3300 pounds. The tests at 84 miles per hour were run for a period of only 30 minutes and it is noticeable that the machine friction dropped to 2600 pounds. It is questionable whether 2600 pounds may be considered representative at 84 m.p.h. on account of the short duration of the tests.

Efficiency of Locomotive.

208. In Fig. 54 is presented graphically the relation between machine efficiency and the speed of the locomotive in miles per hour. To furnish a more comprehensive idea of the performance of the locomotive in respect to this particular feature, curves representing the Hannover Compound, the class K29, K2sa, E6s, E6 and E2a locomotives are given.

209. It is characteristic of this locomotive as of the other locomotives shown, that the machine efficiency decreases as the speed of the locomotive increases. The machine efficiency was 85 per cent. at 35 m.p.h. and decreased to 67 per cent. at 85 miles per hour.

210. Between the speeds of 30 and 35 miles per hour, the machine efficiency of the E3sd is greater than that of the E6s, while at greater speeds the efficiency of the former falls below that of the E6s locomotive.

211. The thermal efficiency based on the fuel fired, is shown graphically in the lower portion of this diagram. It is seen that the thermal efficiency of this locomotive is slightly below that of

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8 x 10½
301 4-29-12

LOCOMOTIVE:
TYPE 4-4-2.
CLASS E3sd No. 318

PENNSYLVANIA RAILROAD COMPANY
PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY
TEST DEPARTMENT

Bulletin No. 11

SHEET NO. P-1112

Tests of a Class E3sd Locomotive. ALTOONA, PA. 11-1-1913

MACHINE FRICTION

Test No.	Test Designation	Duration of Test Mins.	Machine Friction in Horse Power	Mean Effective Pressure Pounds Per Square Inch	Drawbar Pull Pounds	Steam to Engines Pounds Per Hour	Dry Coal Fired per Hour in Pounds	Machine Efficiency Percent
			395	396	397			398
3111	120-20-F	120	248.2	20.84	3324	7401.3	848.8	66.77
3112	120-30-F	120	234.5	19.74	3140	5883.6	738.7	75.19
3137	120-40-F	120	180.5	15.20	2417	3850.1	541.5	84.46
3121	160-30-F	120	192.5	12.16	1933	3892.4	451.0	83.88
3113	160-35-F	120	216.1	13.65	2170	4611.6	581.3	83.55
3114	160-45-F	90	237.6	15.00	2386	5201.1	860.1	85.04
3133	160-50-F	60	192.2	12.14	1930	3855.5	703.5	88.67
3136	200-20-F	120	207.2	10.47	1665	4247.6	551.2	81.65
3115	200-35-F	120	310.1	15.66	2492	6670.3	1010.9	79.98
3134	200-35-F	60	273.3	13.81	2196	5353.9	923.8	82.88
3135	200-35-F	60	235.2	11.88	1890	4449.9	642.1	85.06
3124	200-45-F	90	282.6	14.28	2271	5945.9	1008.9	84.48
3117	240-20-F	120	358.4	15.09	2400	7723.5	1021.4	72.76
3116	240-35-F	90	385.5	16.23	2581	8218.9	1264.4	77.64
3109	240-45-F	60	327.4	13.78	2192	7330.5	1219.9	82.41
3139	240-45-F	60	384.9	16.20	2581	8235.9	1464.5	80.35
3119	280-20-F	90	575.3	20.76	3302	13605.8	1933.0	62.50
3122	280-30-F	60	455.1	16.42	2612	9693.6	1588.3	73.08
3125	280-35-F	60	458.5	16.54	2631	9711.0	1609.3	75.33
3126	320-20-F	60	704.0	22.23	3535	18522.2	2893.4	56.65
3128	320-25-F	60	551.1	17.40	2768	12603.7	1906.8	68.31
3127	320-30-F	60	669.6	21.14	3363	16565.9	3173.9	63.90
3142	360-25-F	30	505.4	14.18	2256	10946.9	2041.8	71.56
3143	360-25-F	30	662.1	18.58	2956	15930.1	3025.8	64.27

SHEET NO. P-1112

Table XIX.
MACHINE FRICTION.
The locomotive friction in terms of drawbar pull in pounds averages 2541 pounds for the tests on this locomotive.

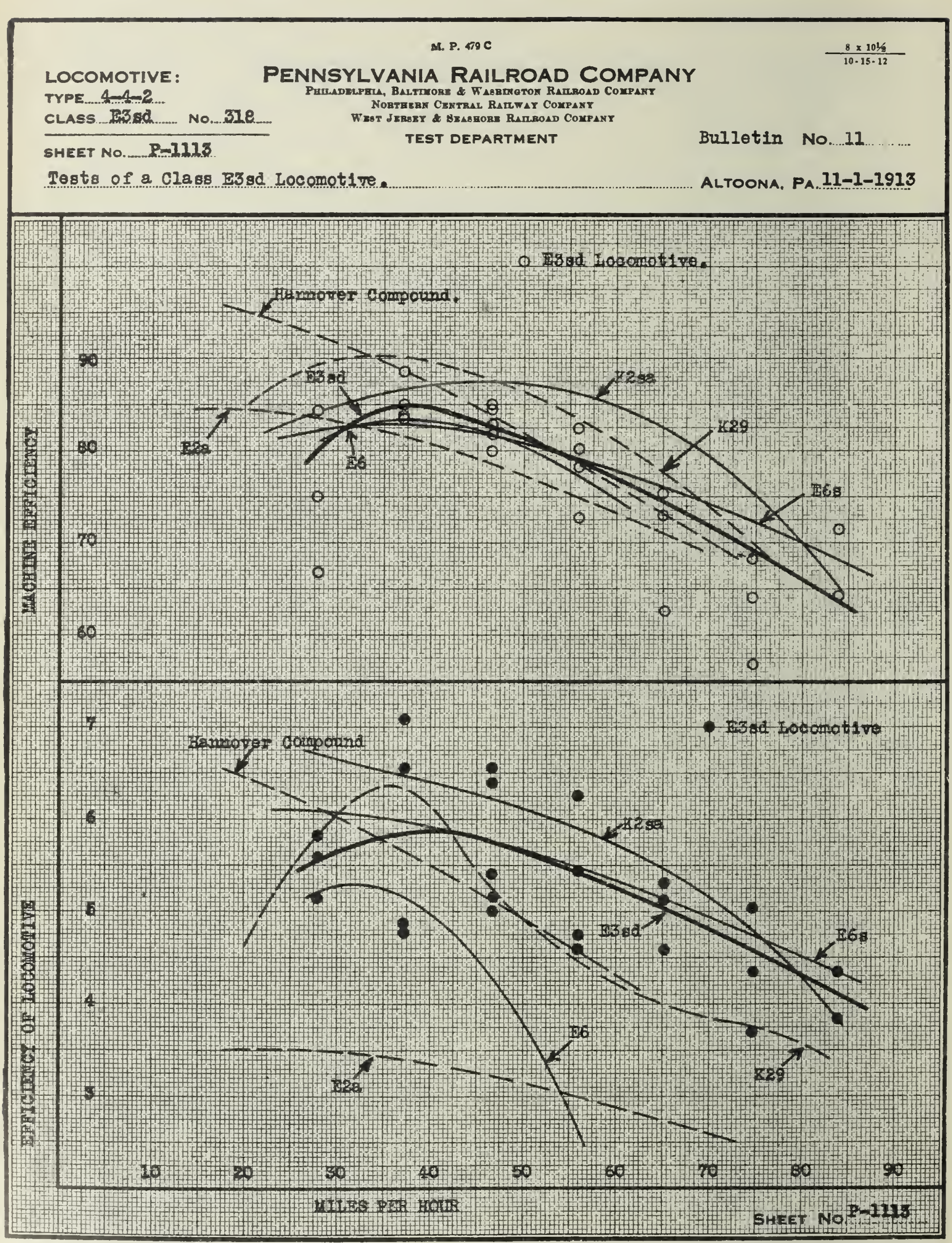


Fig. 54.

LOCOMOTIVE AND MACHINE EFFICIENCY AT VARIOUS SPEEDS.

The machine efficiency for this locomotive compares favorably with that of the other Atlantic type class E locomotives. The locomotive efficiency equals that of the E6s locomotive at speeds between 42 and 50 miles per hour.

the E6s locomotive, except at speeds ranging from 42 to 50 miles per hour, when the efficiency of each is practically equal.

212. The advantages offered by the addition of a superheater and arch, are shown when comparing the curves for the E3sd and E2a locomotives. As mentioned previously, the E2a locomotive used saturated steam in smaller cylinders and did not have an arch, otherwise it was similar in construction aside from valves and valve gear.

213. The study of these curves points out strongly the advantage of using a high degree of superheat in locomotive operation.

Superheat and Thermal Efficiency.

214. Fig. 55 is furnished to show just what effect, if any, the use of varying degrees of superheat supplied to the cylinders of a locomotive of this class, had upon its thermal efficiency.

215. In the upper portion of the diagram is plotted the degrees of superheat in the branch pipe. In the lower portion of the diagram is similarly plotted the degree of superheat in the exhaust. The area intervening between the two curves represents the amount of heat utilized by the locomotive. As shown before in Bulletins Nos. 21 and 18, these curves have a tendency to parallel each other. The difference between the superheat in the live and exhaust steam is nearly constant. From an analysis of the data it appears that whenever there is an increase in the superheat in the branch pipe, there is a corresponding increase in the exhaust superheat, and further, the conditions under which the tests are run have a marked influence on the thermal efficiency, more so, in fact, than the temperature of the superheated steam admitted to the cylinders.

216. Above the various points representing branch pipe steam temperatures are printed the corresponding rates of equivalent evaporation per hour in pounds. At the maximum rate or 46,078 pounds per hour, the thermal efficiency was 4.59 per cent. while the highest efficiency or 7.08 per cent. was attained when the evaporation rate reached but 27,349 pounds per hour.

Coal and Water Saving.

217. A previous discussion of the economy effected in the consumption of fuel and water through no other change than the application of a superheater to a locomotive, was presented

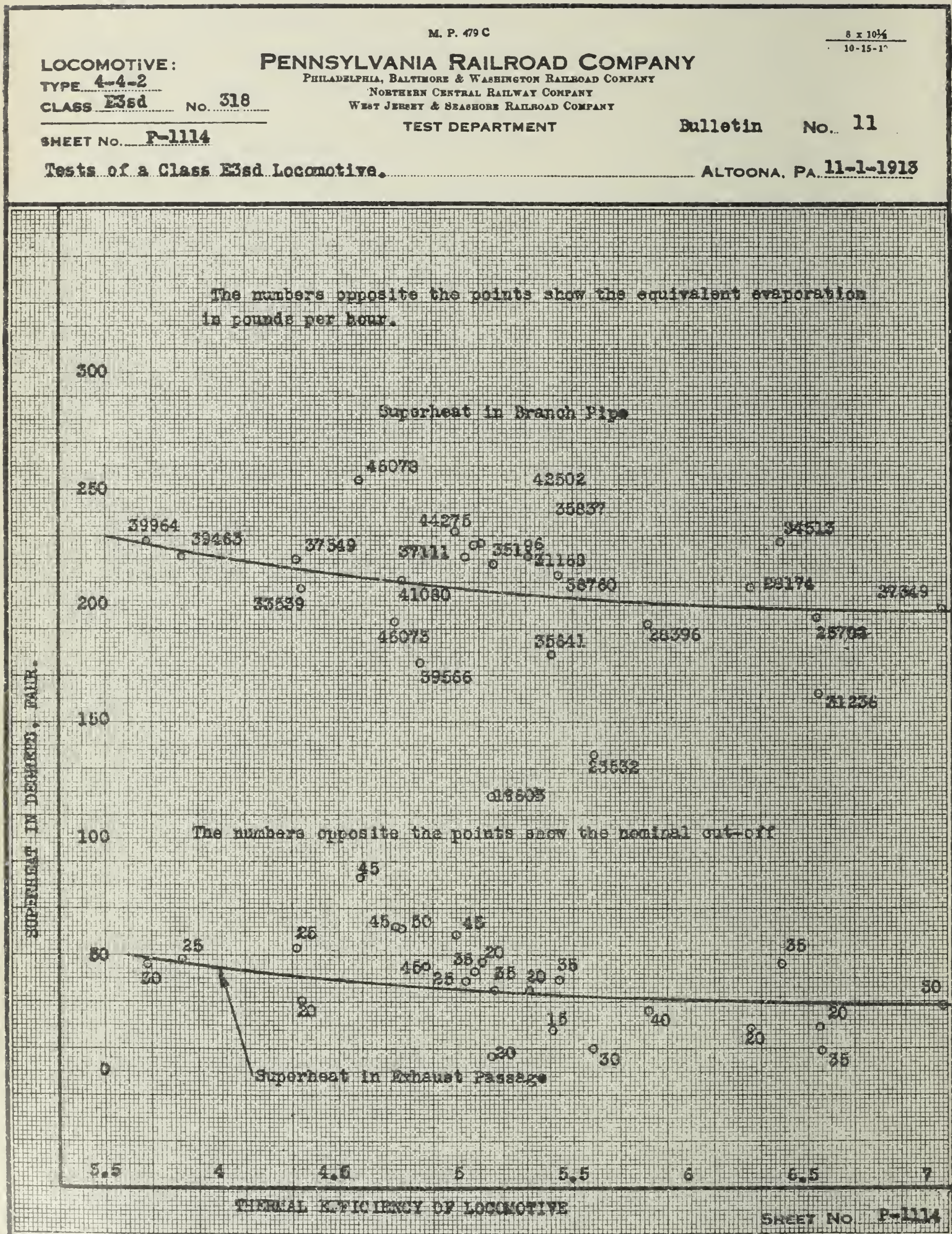


Fig. 55.

SUPERHEAT AND THERMAL EFFICIENCY OF LOCOMOTIVE

The thermal efficiency increases as the superheat decreases.

in Bulletin No. 21, pages 143 to 147 inclusive, "Tests of a class E6s Passenger Locomotive," of the Atlantic Type.

218. The comparison was made between an E6 Atlantic type simple saturated steam locomotive and an E6s locomotive similar in every way with the exception that it contained a Schmidt superheater. The text referred to states the saving to be obtained through the use of the superheater as follows:

(*a*) The saving in water of 28 per cent. at the full load of the E6 locomotive.

(*b*) A saving in fuel of 30 per cent. assuming the normal full load of the E6 locomotive to be 1200 horsepower.

(*c*) Thus, the capacity of the E6s locomotive was increased approximately 30 per cent. above that of the E6 saturated steam locomotive through the application of the superheater.

219. We are now able to make a similar comparison, but under more ideal conditions, between the E3sd and E2d Atlantic type simple locomotive.

220. When the E6 saturated steam locomotive was modified to use superheated steam, the same cylinder dimensions were retained, as were originally used for saturated steam. A just comparison illustrating the full advantage to be obtained by superheating was impossible for that reason. Theoretically it was apparent that to derive the greatest benefit from the use of superheated steam the diameter of the cylinders should have been increased. This fact was brought out in the tests of the E6s superheated steam locomotive (Bulletin No. 21, Par. 12 of Conclusions).

221. The E2d locomotive, as originally designed for saturated steam, had cylinders 20½ inches in diameter. The E3d locomotive to which a superheater was applied has a diameter of cylinder of 22 inches. This enlargement of the steam cylinders has been instrumental in producing an economy in the water and fuel rate with the use of superheated steam which is remarkable.

222. Both locomotives were hand-fired. As previously mentioned the only differences existing between the E2d and E3sd locomotives were, that the latter had a superheater, an arch and a larger cylinder diameter.

223. In order to present more clearly an idea of the saving in steam obtained from the E3sd superheated steam locomotive, three curves are shown in Fig. 56. These illustrate the weight of steam used per dynamometer horse-power hour by the superheated steam locomotive, the saturated steam locomotive and the saving in per cent. by using superheated steam.

224. The saving in steam is seen to increase rapidly with the increase in power. The economy ranges from 6 per cent. at 500 d.h.p to 31 per cent. at 1150 d.h.p., the maximum power of the E2d saturated steam locomotive.

225. As mentioned previously in this Bulletin we are unable to plot comparative curves showing the saving in fuel based on the dynamometer horse-power output of the E2d and E3sd locomotives. This is due to the fact that the majority of tests pertaining to the locomotive performance of the E2d saturated steam locomotive were of such short duration as to make their fuel rates unreliable as a basis of comparison.

226. However, a test made on the E2d saturated steam locomotive, of an hour's duration, may be offered to give some idea of the fuel economy to be obtained from the E3sd locomotive when compared with the E2d at its maximum power output. This test was run at 200 r.p.m. with a full throttle and 30 per cent. cut-off. The dynamometer horse-power developed was 1044.3. The fuel consumption per d.h.p. hour reached 5.37 pounds. A test at the same speed with full throttle and 35 per cent. cut-off was made on the E3sd locomotive for a like period. The dynamometer horse-power obtained was 1339.6, and the fuel consumption per d.h.p. was 2.73 pounds. There is thus a saving of 48.4 per cent. in fuel.

227. At 120 r.p.m. and 30 per cent. cut-off a two hour test on the E2d saturated locomotive with a full throttle was made. The fuel consumption was 3.46 pounds per d.h.p. hour. A similar test on the E3sd locomotive required a fuel consumption of 3.15 pounds per d.h.p. hour, thus a saving in fuel of approximately 10 per cent. was effected at a low power test.

228. Thus, we may state that the saving in fuel for the E3sd superheater locomotive increases with the power output from 10 per cent. at 710 d.h.p. to 48.4 per cent. at 1340 d.h.p.

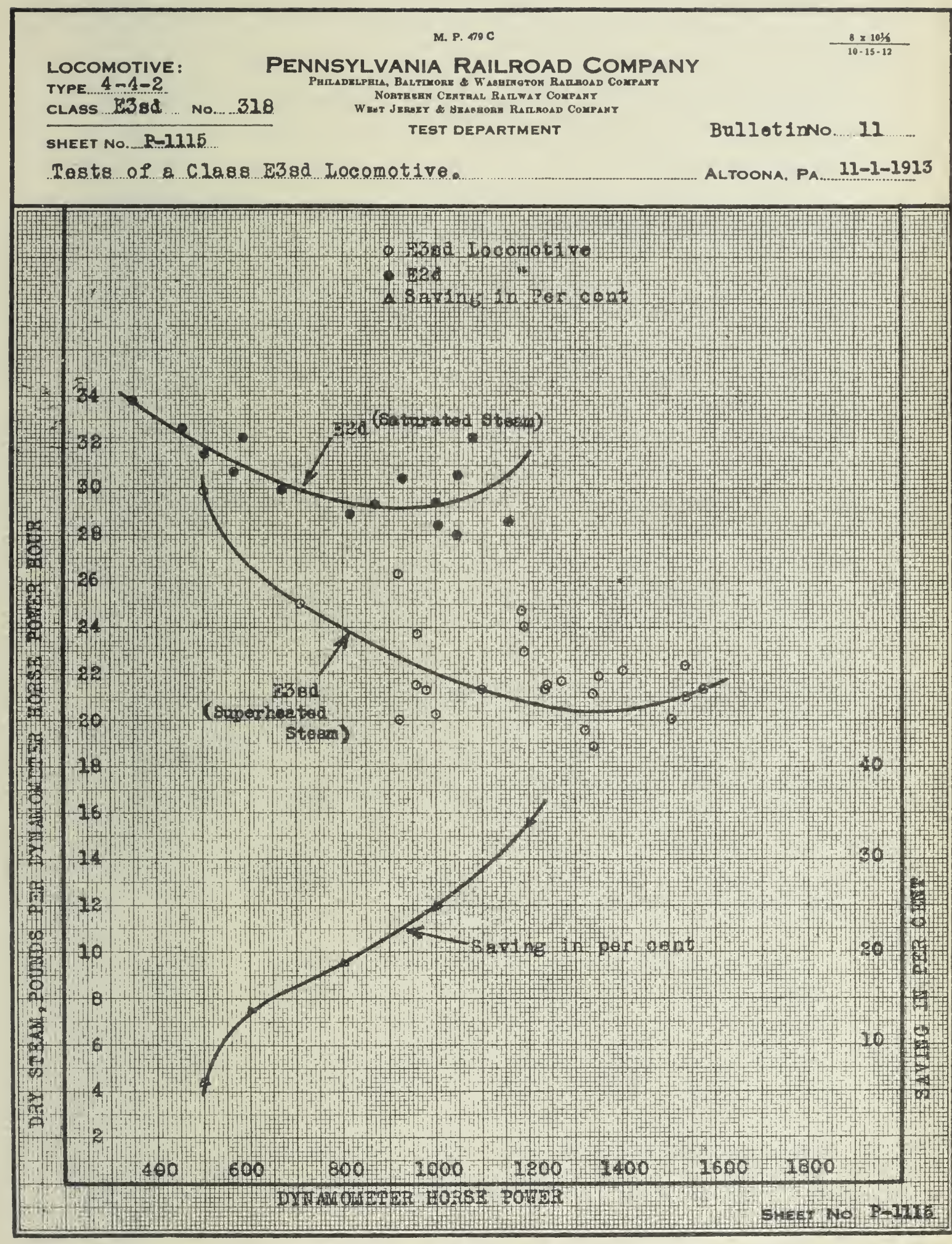


Fig. 56.

STEAM PER DYNAMOMETER HORSE-POWER HOUR AND DYNAMOMETER HORSE-POWER

The economy in steam obtained by superheating increases rapidly with the increase in power.

229. Assuming the normal full load of the E2d, saturated steam locomotive, to approximate 1000 d.h.p. it is seen that the application of a superheater has increased the power capacity of the E3sd locomotive to 1550 d.h.p. or 55 per cent. Thus the superheater is a considerable factor in the designing of a locomotive for high power.

230. Therefore, the conclusions may be conservatively drawn that the superheated steam locomotive, class E3sd, will effect a saving in fuel of approximately 48 per cent. and a saving in water of 31 per cent., based on the consumption of the E2d saturated steam locomotive at its maximum capacity.

231. The application of a superheater increased the maximum capacity of the E6s superheated steam locomotive 30 per cent. over the E6 saturated steam locomotive (Bulletin No. 21, Par. 178). In the case of the E3sd locomotive the increase was 55 per cent. or more. The greater increase in dynamometer horse-power is no doubt largely due to the fact of an increase in the diameter of the cylinders on the E3sd superheater locomotive, as compared with the E2d saturated steam locomotive.

232. It may be safely stated that the tonnage rating of the E3sd superheater locomotive may be increased 30 per cent. above that of the E2d saturated steam locomotive, when low speeds approximating 28 m.p.h. and the starting of trains are not factors of prime importance. There seems no question but what the increased economy in fuel and water of the locomotive justifies this increase in the tonnage rating.

233. Referring to Fig. 51 it is also observed that much higher speeds may be maintained with the E3sd superheated steam locomotive than with the E2d saturated steam locomotive when hauling trains of like tonnage.

CONCLUSIONS.

BOILER.

1. It is apparent from a study of these tests that the boiler design of this locomotive has fulfilled the necessary requirements. The very favorable grate performance obtained indicates a well proportioned firebox and a proper supply of air. Data has also been presented which indicate that the 2-inch tubes (180 inches long) are of the most advantageous length to absorb heat without impairing either the combustion or evaporation rates (Par. 109).

2. The brick arch plays an important part in reducing the amount of smoke. It enables a considerable portion of it to be burned (Par. 57).

3. As the maximum combustion rate in ordinary road service would not greatly exceed 5000 pounds of coal per hour, the application of a stoker to the firebox of this locomotive would not seem warranted.

4. The ashpan air inlets of the locomotive have an area equal to 12 per cent. of the grate, and the indications are that this opening is not sufficient. In the case of the E6s locomotive, an area of 14 per cent. was found large enough (Bulletin No. 21, Par. 31).

LOCOMOTIVE.

5. The use of highly superheated steam at 205 pounds boiler pressure, brought about an economy in steam of approximately 34 per cent. (Par. 138), and the superheater together with an arch show a saving in coal increasing from 10 to 48 per cent., with the power output. Characteristic of superheater locomotives the tendency is to keep the coal consumption per dynamometer horsepower hour under 4 pounds. This locomotive is most economical in fuel consumption when running at speeds under 60 m.p.h. (Fig. 46).

6. Comparing the water rate for this E3sd locomotive with other locomotives tested on the Plant, we find that this simple locomotive with its large cylinders and highly superheated steam outstrips all other locomotives at piston speeds up to 1400 feet per minute, with the exception of the Hannover Compound using a medium degree of superheat. At piston speeds above 1400 feet per minute its performance is not quite equal to that of the K2sa simple superheated steam locomotive of the Pacific type (Fig. 47).

7. A comparison with the E2d saturated steam locomotive shows that the superheated steam locomotive exhausts with less than half the least back pressure of the saturated steam locomotive (Par. 147).

8. A comparison of the least back pressure for the E3sd and E6s superheater locomotives shows a greater back pressure for the E3sd locomotive. This is probably due to the design of the exhaust passage in the cylinders of the E3sd locomotive (Pars. 152 to 155).

9. The maximum capacity of the boiler is reached at a speed of 38.5 miles per hour and a cut-off of 50 per cent. The drawbar pull is then 15,000 pounds. To exceed this speed it is necessary to reduce the cut-off below 50 per cent. (Par. 193).

10. It was also found that with the application of a superheater, the drawbar pull could be increased 14 per cent. at 20 m.p.h. and 39 per cent. at 50 m.p.h. (Par. 199).

11. Assuming the normal full load of the E2d saturated steam locomotive to be 1000 dynamometer horse-power, the application of larger cylinders, using highly superheated steam, increased the d.h.p. of the E3sd locomotive 55 per cent. or to 1550 d.h.p. (Par. 229).

12. Higher speeds can be maintained with the superheater locomotive than with a like saturated steam locomotive when hauling trains of like tonnage.

13. The tonnage may be increased 30 per cent. when low speeds approximating 28 miles per hour, and the starting of trains are not of prime importance. This is due to the application of the superheater and the use of larger cylinders.

Recommendations.

1. We would recommend the application of superheaters to the E class locomotives according to the following program:

2. The E2, E2a, E3 and E3a classes which now have slide valves and Stephenson valve gear, to have superheaters applied when new cylinders are needed. The new cylinders to have piston valves and Walschaerts valve gear.

3. The E2d and E3d classes to have superheater applied when they require the renewal of the back tube sheet.

4. All new cylinders applied to these locomotives should be arranged for 12-inch diameter valves, and they should have a cylinder diameter of 22 inches so that all locomotives of these older E classes will become as nearly as possible like the class E3sd.

5. We recommend that the ashpan air inlets be made not less than 15 per cent. of the grate area.

C. D. YOUNG,
Engineer of Tests.

Approved:
J. T. WALLIS,
General Supt. Motive Power.

Test Department,
Altoona, Penna.,
January 14, 1914.

TESTS OF CLASS E3SD SUPERHEATED STEAM LOCOMOTIVE No. 318.

On pages 127 to 136 are shown test results for class E3sd locomotive No. 318.

(M. P. Special.)

(Sheet No 1.)

PENNSYLVANIA RAILROAD COMPANY.

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY.
NORTHERN CENTRAL RAILWAY COMPANY.
WEST JERSEY & SEASHORE RAILROAD COMPANY.

TEST DEPARTMENT.
LOCOMOTIVE TESTING PLANT.

TEST OF LOCOMOTIVE No. 318 TYPE 4-4-2 CLASS E6d BUILT AT. Juniata Shops, Altoona, Penna., 1906

Atlantic Type Passenger Locomotive With Arch and Superheater. PRESENTED FOR TEST BY Pennsylvania Railroad Company

TESTED AT. Locomotive Test Plant, Altoona - Penna. TESTED January 1913 TEST Nos. 3109 TO 3143 SERIES No. 3100

No.	DESCRIPTION, DIMENSIONS AND PROPORTIONS.	
	DRIVING WHEELS.	
1	Number of pairs	2
2	Approximate diameter, inches	80
	MEASURED CIRCUMFERENCE, FEET.	
3	Right, No. 1	20.54
4	" " 2	20.54
5	" " 3	-
6	" " 4	-
7	" " 5	-
8	Left, " 1	20.54
9	" " 2	20.54
10	" " 3	-
11	" " 4	-
12	" " 5	-
13	Average	20.54
	ENGINE TRUCK WHEELS.	
14	Number	4
15	Diameter, inches	36
	TRAILING WHEELS.	
16	Diameter, inches	50
	WHEEL BASE, FEET.	
17	Driving wheel base	7.42
18	Total wheel base	30.79
19	Gauge of wheels, in inches	56.5
	DESCRIPTIONS, DIMENSIONS AND PROPORTIONS	
	VALVES.	
82	Type	Piston
83	Design	American Balance Valve Company
84	Per cent. of balanced to total area	100
85	Type of link motion	Walschaerts
	GREATEST VALVE TRAVEL, INCHES.	
86	High pressure, right	6.44
87	" " left	6.40
88	Low " right	-
89	" " left	-
	Steam LAP OF VALVE, INCHES.	
90	High Pressure, right, head end	1.29
91	" " crank "	1.29
92	" left, head "	1.29
93	" " crank "	1.29
94	Low right, head "	-
95	" " crank "	-
96	" left, head "	-
97	" crank "	-
	Exhaust LAP OF VALVE, INCHES.	
98	High Pressure, right, head end	0.295
99	" " crank "	0.295
100	" left, head "	0.280
101	" " crank "	0.280
102	Low " right, head "	-
103	" " crank "	-
104	" " left, head "	-
105	" " crank "	-
	MISCELLANEOUS.	
106	Cylinder lagging material	Magnesia
107	" jacket "	Sheet Iron
108		
109		

No.	WEIGHT OF ENGINE WITH WATER AT 2ND GAUGE COCK AND NORMAL FIRE, IN POUNDS.	
20	On truck	27200
21	" 1st drivers	64100
22	" 2nd "	63600
23	" 3rd "	-
24	" 4th "	-
25	" 5th "	-
26	" trailers	30300
27	Total	185400
28	" on drivers	127900
	CYLINDERS.	
29	High pressure, number	2
30	Low "	-
31	Arrangement	Outside
	DIAMETER, INCHES.	
32	High pressure, right	22.258
33	" " left	22.024
34	Low " right	-
35	" " left	-
	STROKE OF PISTON, FEET.	
36	High pressure, right	2.152
37	" " left	2.150
38	Low " right	-
39	" " left	-
110		
111		
112		
	BOILER.	
113	Type	Belpaire, Wide Firebox
114	Outside diameter, 1st ring, inches	70.95
	TUBES.	
115	Number	170
116	Outside diameter, inches	2.0
117	Thickness, inches	0.125
118	Length between tube sheets, inches	179.71
119	Total fire area, square feet	4.64
120	Serve Tubes, number of ribs	-
121	" sq. in. of inside surface in one in. of length	-
122	Superheater flues, number	24
123	" " diameter in.	5.375
124	Boiler pressure in pounds per sq.in.	205
	SUPERHEATER.	
125	Number of tubes	96
126	Outside diameter, inches	1.50
127	Thickness, inches	0.149
128	Length of tubes, inches. Total.	16200
129	Heating surface (Fireside) tubes sq.ft.	523.70
130	" " Header sq.ft.	17.50
131	" " return bends.	19.40
	FIRE BOX (SIZE INSIDE, INCHES.)	
132	Length	116.32
133	Width	67.50
134	Depth, front end	61.0
135	" back "	55.75
136	Volume, cubic feet	199.83
137	Air inlets to ashpan sq. ft.	6.54
138		
139	Brick arch, volume, cu. ft.	7.05
140	Arch pipe. " " "	1.34

No.	CLEARANCE PER CENT. OF PISTON DISPLACEMENT.	
40	H. P., right, head end (Determined by Clayton Method)	7.0
41	" " crank " " "	7.0
42	" left, head " " "	7.0
43	" " crank " " "	7.0
44	L. P., right, head "	-
45	" " crank "	-
46	" left, head "	-
47	" " crank "	-
	RECEIVER, CUBIC FEET.	
48	Volume, right side	-
49	" left "	-
	STEAM PORTS, INCHES. (For piston valves the length equals the circumference of inside of bushing minus the sum of the widths of bridges.)	
50	H. P. admission, right, head end, length	36.09
51	" " " " " width	2.02
52	" " " crank " length	36.52
53	" " " " " width	2.05
54	" " left, head " length	36.40
55	" " " " " width	2.01
56	" " " crank " length	36.54
57	" " " " " width	2.06
58	L. P " right, head " length	-
59	" " " " " width	-
	FIRE DOORS.	
141	Number	1
142	Area, square feet	1.58
143	Heating surface, arch pipe (fireside) sq. ft.	21.50
	GRATES.	
144	Style	Rocking Finger
145	Total area, square feet	54.70
146	" " dead grates, square feet	
147	Width of air spaces, inches	0.75
	AIR INLET AREAS, SQUARE FEET.	
148	Through firebox sides	0.017
149	" grates	16.47
150	" fire doors	0.06
151	Total air inlets, (148), (149) and (150).	16.55
152	Ratio " " (149) to grate area (145).	0.30
153	" " " (151) to " " (145).	0.30
	HEATING SURFACE, SQUARE FEET.	
154	Of the tubes, water side	1836.10
155	" " fire "	1641.50
156	" firebox, fire side including arch pipe	179.42
157	" " superheater, fire side	560.60
158	Total, based on inside of firebox and inside of tubes including superheater	2381.52
159	" " outside of tubes	2576.12
	BOILER VOLUMES With water surface at level of second gauge cock.	
160	Water space, cubic feet	334.89
161	Steam " "	107.72
	EXHAUST NOZZLE.	
162	Double or single	Single
163	Size of right, inches	
164	" " left, " Rectangular	4-1/4 x 6 in.
165	Area of right, square inches	-
166	" " left, "	-
167	Total area, square inches	25.44

No.		
60	L. P. admission, right, crank end, length	-
61	" " " " " width	-
62	" " left, head " length	-
63	" " " " " width	-
64	" " " crank " length	-
65	" " " " " width	-
66	H. P. exhaust, right, length	No Port
67	" " " width	"
68	" " left, length	"
69	" " " width	"
70	L. P. " right, length	-
71	" " " width	-
72	" " left, length	-
73	" " " width	-
	PISTON RODS, DIAMETER, INCHES.	
74	High pressure, right	3.954
75	" " left	3.908
76	Low " right	-
77	" " left	-
	TAIL RODS, DIAMETER, INCHES.	
78	High pressure, right	-
79	" " left	-
80	Low " right	-
81	" " left	-
	REVERSE LEVER.	
168	H. P. cylinder, notches forward of centre	16
169	L. P. " " " " "	-
170		
	RATIOS.	
171	Heating surface (158) to grate area (145)	43.54
172	Fire area through tubes (119) to grate area (145)	0.085
173	Firebox heating surface (156) to grate area (145)	3.29
174	Tube surface (159) to firebox heating surface (156)	10.29
175	Firebox volume (136) to grate area (145)	3.65
176		
177		
178		
	CONSTANTS	
179	For dynamometer H. P., (power developed when the speed is one R. P. M. and the pull is one pound)	0.0006213
	FOR INDICATED HORSE POWER, (power developed at one R. P. M. and one pound M. E. P.)	
180	High Pressure Cylinder, right, head end	0.02557
181	" " " " crank "	0.02457
182	" " " left, head "	0.02491
183	" " " " crank "	0.02413
184	Low " " right, head "	-
185	" " " " crank "	-
186	" " " left, head "	-
187	" " " " crank "	-
	FOR PISTON DISPLACEMENT, CUBIC FEET.	
188	High pressure Cylinder, right, head end	6.2271
189	" " " " crank "	6.2271
190	" " " left, head "	6.1088
191	" " " " crank "	6.1088
192	Low " " right, head "	-
193	" " " " crank "	-
194	" " " left, head "	-
195	" " " " crank "	-

(M. P. Special.) TEST OF LOCOMOTIVE No. 718 TYPE 4-4-2 CLASS E3sd (Sheet No. 3.)

SUMMARY OF AVERAGE RESULTS.

Test Number	Laboratory Designation	Duration of Test, Hours	Speed: Revolutions: Total	Speed: Revolutions: Average Per Minute	Speed: Equivalent: Speed in Miles Per Hour	Speed: Equivalent: Piston Speed in Feet Per Minute	Position of Levers: Reverse, Notches From Front End	Position of Levers: Average Cut-off	Position of Levers: Throttle			Temperature, Degrees Fahrenheit, of: Smoke Box: By Thermometer	Smoke Box: By Pyrometer	Laboratory: Dry Bulb	Laboratory: Wet Bulb	Steam in Branch Pipe By Thermometer	Feed Water	Fire Box by Pyrometer		Steam per Hour to Engines, Pounds	Fuel Loss due to Steam Loss Pounds per Hour	Steam Lost from Boiler Pounds per Hour
		196	197	198	199	200	201	202	203	204	205	206	207	208	209	210	211	212	213	214	215	216
3111	120-20-F	2.00	14400	120	28.01	517.2	14.5	18.3	Full				471	58	57	505.2	43.7	1897		14872	29.54	262
3112	120-30-F	2.00	14400	120	28.01	517.2	13.5	25.2	"				433	50	48	525.8	43.8	1979		17828	23.51	189
3137	120-40-F	2.00	14400	120	28.01	517.2	12.5	34.4	"				691	56	51	579.4	43.3	2122		20921	52.76	382
3121	160-30-F	2.00	19200	160	37.34	689.6	13.5	26.4	"				669	64	58	585.7	41.7	1852		20246	23.36	189
3113	160-35-F	2.00	19200	160	37.34	689.6	13.0	31.5	"				500	49	46	548.2	42.3	2197		33422	34.50	277
3114	160-45-F	1.50	14400	160	37.34	689.6	11.5	41.1	"				736	56	51	559.8	42.0	2348		29571	44.68	273
3133	160-50-F	1.00	9600	160	37.34	689.6	11.0	42.8	"				722	58	55	594.9	42.2	2170		30184	67.81	377
3136	200-20-F	2.00	24000	200	46.66	862.0	14.5	21.2	"				673	61	58	582.6	43.1	1962		18900	45.22	355
3115	200-35-F	2.00	24000	200	46.68	862.0	13.0	32.7	"				725	54	52	564.2	42.0	-		26644	28.46	189
3135	200-35-F	1.00	12000	200	46.68	862.0	13.0	31.1	"				703	60	56	612.9	43.3	2200		25343	31.66	221
3134	200-35-F	1.00	12000	200	46.68	862.0	13.0	31.5	"				699	62	58	602.9	44.0	2235		25917	38.87	227
3124	200-45-F	1.50	18000	200	46.68	862.0	11.5	41.5	"				734	64	62	614.4	43.9	2188		32353	68.51	409
3117	240-20-F	2.00	28800	240	56.02	1034.0	13.0	22.8	"				660	54	50	595.7	42.0	1940		20626	45.19	348
3116	240-35-F	1.50	21600	240	56.02	1034.4	13.0	33.4	"				711	48	46	598.8	43.8	2163		28546	44.21	290
3109	240-45-F	1.00	14400	240	56.02	1034.4	11.5	42.1	"				730	58	56	570.9	44.0	2322		34360	42.17	256
3139	240-45-F	1.00	14400	240	56.02	1034.4	11.5	41.9	"				748	59	56	632.3	43.0	2249		33628	39.58	224
3119	280-20-F	1.50	25200	280	65.35	1206.8	14.5	25.7	"				688	55	53	607.8	42.0	1838		22682	55.51	398
3122	280-30-F	1.00	16800	280	65.35	1206.8	13.5	37.1	"				712	63	60	609.1	42.0	2164		26311	35.70	220
3125	280-35-F	1.00	16800	280	65.35	1205.6	13.0	33.4	"				728	58	63	610.9	44.3	2197		31064	72.70	466
3126	320-20-F	1.00	19200	320	74.69	1379.2	14.5	21.2	"				699	62	60	593.1	43.0	1871		24208	119.18	789
3128	320-25-F	1.00	19200	320	74.69	1379.2	14.0	25.8	"				718	67	64	607.1	44.0	1922		27282	100.88	687
3127	320-30-F	1.00	19200	320	74.67	1379.2	14.5	30.5	"				743	64	61	612.3	44.7	2063		29318	58.71	310
3142	360-25-F	0.50	10800	360	84.02	1551.6	14.0	31.2	"				-	59	55	602.0	42.0	2224		27546	60.96	331
3143	360-25-F	0.50	10800	360	84.02	1551.6	14.0	31.6	"				-	59	55	605.5	43.0	2206		28655	120.26	647

(M. P. Special.) TEST OF LOCOMOTIVE No. 318 TYPE 4-4-2 CLASS K3d (SHEET No. 4)

SUMMARY OF AVERAGE RESULTS.

Test Number	Laboratory Designation	Pressure, Pounds per Square Inch. In Boiler. Average.	In Boiler. Maximum.	In Boiler. Minimum.	In Branch Pipe.	Air in Laboratory, Barometric.	Draft, Inches of Water. In Smoke Box. Front of Diaphragm.	In Smoke Box. Back of Diaphragm.	In Fire Box.	In Ash Pan.	Injectors. Hours in Action. Total, Right.	Total, Left.	Quality of Steam. In Dome. Per Cent	In Branch Pipe.	Degrees of Superheat in Branch Pipe.	Factor of Correction	Coal, Sparks and Ash, Pounds. Coal Fired. Kind.	Coal Fired. Total.	Per Cent. of Moisture.	Total. Dry Coal Fired.	Combustible by Analysis.	Ash by Analysis.
		217	218	219	220	221	222	223	224	225	226	227	228	229	230	231	232	233	234	235	236	237
3111	120-20-F	203.6	206	201	198.2	14.42	3.3	2.00	0.4	0.08	2.00		99.49		118.15	0.9964	Bituminous	3470	1.68	3412	3195	247
3112	120-30-F	205.2	206	202	199.2	14.38	4.4	2.70	0.4	0.12	2.00		99.46		138.37	0.9962	"	4556	1.68	4479	4195	324
3137	120-40-F	206.0	206	206	198.0	14.10	5.7	4.30	1.3	0.08	2.00		99.55		192.56	0.9968	"	6000	1.95	5883	5527	356
3121	160-30-F	205.5	206	205	196.5	14.27	5.9	4.10	1.0	0.15	2.00		99.45		199.39	0.9961	"	5140	1.69	5053	4669	419
3113	160-35-F	205.5	206	203	197.2	14.29	7.2	5.10	0.7	0.18	2.00		99.48		161.60	0.9963	"	6000	1.68	5899	5525	427
3114	160-45-F	205.5	206	204	192.6	14.23	10.9	8.20	1.2	0.30	1.50		99.49		175.07	0.9964	"	7457	1.68	7332	6867	531
3133	160-50-F	203.4	206	202	189.3	14.02	10.6	7.9	2.4	0.16	1.00		99.39		211.67	0.9957	"	5610	1.95	5501	5196	344
3136	200-20-F	205.8	206	204	198.8	14.09	4.6	2.9	0.8	0.06	2.00		99.54		195.44	0.9968	"	5000	1.95	4903	4606	307
3115	200-35-F	205.0	206	200	193.2	14.14	9.3	7.0	1.3	0.23	2.00		99.51		179.26	0.9966	"	8221	1.68	8083	7570	585
3135	200-35-F	206.0	206	206	194.7	14.13	8.0	5.6	1.7	0.12	1.00		99.51		227.37	0.9966	"	3736	1.95	3663	3442	229
3134	200-35-F	205.1	206	204	193.0	14.15	8.3	5.8	1.8	0.13	1.00		99.51		218.04	0.9966	"	4566	1.95	4477	4206	280
3124	200-45-F	203.0	206	197	186.4	14.04	12.3	8.8	2.6	0.34	1.50		99.46		232.32	0.9962	"	8378	1.69	8236	7595	683
3117	240-20-F	206.0	206	206	198.8	14.34	6.0	4.3	1.1	0.12	2.00		99.51		208.44	0.9966	"	5542	1.69	5448	5024	452
3116	240-35-F	205.4	206	203	192.7	14.39	9.9	7.4	2.4	0.30	1.50		99.46		213.96	0.9962	"	6706	1.69	6593	6079	547
3109	240-45-F	195.9	206	183	175.6	14.04	13.7	9.8	1.6	0.41	1.00		99.50		193.44	0.9965	"	5800	1.68	5703	5341	413
3139	240-45-F	196.4	206	189	178.0	13.92	12.8	9.1	2.5	0.21	1.00		99.50		253.84	0.9965	"	6094	1.95	5977	5616	374
3119	280-20-F	206.0	206	206	197.4	14.39	7.6	5.4	1.4	0.10	1.50		99.49		221.08	0.9964	"	4912	1.69	4829	4453	400
3122	280-30-F	197.1	206	188	185.4	14.23	10.3	8.0	2.6	0.27	1.00		99.47		227.38	0.9963	"	4388	1.69	4314	3978	358
3125	280-35-F	205.7	206	205	191.7	14.16	11.3	8.2	2.1	0.24	1.00		99.46		226.80	0.9962	"	5000	1.69	4916	4533	408
3126	320-20-F	205.6	206	205	195.1	14.08	8.0	6.0	2.0	0.11	1.00		99.50		207.43	0.9965	"	3842	1.69	3777	3483	313
3128	320-25-F	205.9	206	205	195.0	14.25	9.3	6.7	1.7	0.13	1.00		99.43		221.40	0.9960	"	4190	1.95	4108	3881	357
3127	320-30-F	204.5	206	202	190.8	14.23	11.4	8.6	2.4	0.13	1.00		99.45		228.29	0.9961	"	5728	1.95	5616	5305	352
3142	360-25-F	196.8	206	190	184.5	13.93	9.8	7.2	3.3	0.11	0.50		99.53		220.83	0.9967	"	2620	1.95	2569	2414	161
3143	360-25-F	205.8	206	205	191.0	14.08	10.3	7.6	3.1	0.13	0.50		99.47		221.47	0.9963	"	2770	1.72	2722	2534	188

(M. P. Special.) TEST OF LOCOMOTIVE No. 318 TYPE 4-4-2 CLASS E3sd (SHEET No. 5)

SUMMARY OF AVERAGE RESULTS.

Test Number	Laboratory Designation	Coal, Sparks and Ash, Lbs. Total: Cinders Collected in Smoke Box	Sparks Discharged From Stack	Cinders and Sparks	Analysis of Coal, Per Cent: Fixed Carbon	Volatile Matter	Moisture	Ash	Sulphur, Determined Separately	Water Level Inches in Gauge Glass		Calorific Value per Lb. of Fuel, B. T. U.: Of Dry Coal	Of Combustible	Of Cinders and Sparks			Analysis of Smoke Box Gases, Per Cent: Oxygen O	Carbon Monoxide CO	Carbon Dioxide CO2	Nitrogen N		Average Smoke Percent Ringelmann Scale
		238	239	240	241	242	243	244	245	246	247	248	249	250	251	252	253	254	255	256	257	258
3111	120-20-F				56.78	35.30	0.80	7.12	2.06	4.0		14442	15558				5.4	0.0	12.6	82.0		8
3112	120-30-F				56.78	35.30	0.80	7.12	2.06	4.5		14442	15558				4.2	0.0	13.0	82.7		10
3137	120-40-F				58.46	34.16	1.24	6.14	2.10	4.0		14581	15547				4.0	0.4	13.2	82.3		16
3121	160-30-F				56.38	34.27	1.20	8.15	1.98	4.0		14266	15549				3.0	0.3	14.5	82.2		16
3113	160-35-F				56.78	35.30	0.80	7.12	2.06	4.0		14442	15558				2.8	0.4	14.3	82.6		14
3114	160-45-F				56.78	35.30	0.80	7.12	2.06	4.0		14442	15558				1.3	2.9	13.5	82.3		40
3133	160-50-F				58.46	34.16	1.24	6.14	2.10	4.5		14581	15547				0.9	3.3	13.4	82.3		32
3136	200-20-F				58.46	34.16	1.24	6.14	2.10	4.0		14581	15547				3.8	0.3	13.8	82.1		14
3115	200-35-F				56.78	35.30	0.80	7.12	2.06	4.0		14442	15558				1.6	1.6	14.3	82.5		32
3135	200-35-F				58.46	34.16	1.24	6.14	2.10	4.0		14581	15547				1.3	1.3	14.7	82.7		18
3134	200-35-F				58.46	34.16	1.24	6.14	2.10	4.0		14581	15547				0.8	2.3	14.1	82.7		22
3124	200-45-F				56.38	34.27	1.20	8.15	1.98	4.0		14266	15549				1.2	1.8	14.4	82.6		46
3117	240-20-F				56.38	34.27	1.20	8.15	1.98	4.0		14266	15549				4.6	0.0	13.6	81.8		20
3116	240-35-F				56.38	34.27	1.20	8.15	1.98	3.0		14266	15549				3.6	0.5	13.6	82.3		32
3109	240-45-F				56.78	35.30	0.80	7.12	2.06	4.5		14442	15558				1.1	3.3	12.8	82.8		42
3139	240-45-F				58.46	34.16	1.24	6.14	2.10	4.0		14581	15547				0.7	3.3	13.9	82.1		36
3119	280-20-F				56.38	34.27	1.20	8.15	1.98	4.0		14266	15549				1.8	1.0	14.0	83.2		28
3122	280-30-F				56.38	34.27	1.20	8.15	1.98	4.5		14266	15549				1.5	2.8	13.4	82.3		40
3125	280-35-F				56.38	34.27	1.20	8.15	1.98	4.0		14266	15549				5.0	0.4	12.0	82.6		22
3126	320-20-F				56.38	34.27	1.20	8.15	1.98	4.0		14266	15549				3.6	0.3	13.1	83.0		16
3128	320-25-F				58.46	34.16	1.24	6.14	2.10	4.5		14581	15547				2.2	0.6	14.6	82.6		24
3127	320-30-F				58.46	34.16	1.24	6.14	2.10	4.5		14581	15547				1.1	2.8	13.1	83.0		40
3142	360-25-F				58.46	34.16	1.24	6.14	2.10	4.0		14581	15547				1.6	1.2	13.6	83.6		32
3143	360-25-F				57.37	34.11	1.72	6.80	1.25	4.5		14541	15622				0.3	4.4	13.	82.1		28

(M. P. Special.) TEST OF LOCOMOTIVE NO. 518 TYPE 4-4-2 CLASS E6d (Sheet No. 6)

SUMMARY OF AVERAGE RESULTS.

Test Number	Laboratory Designation	Water, in Pounds: Delivered to Injectors	Water, in Pounds: Lost: From Boiler	Water, in Pounds: Lost: From Injectors	Water, in Pounds: Lost: From	Water, in Pounds: Lost: Total	Water, in Pounds: Delivered to Boiler and Presumably Evaporated	Dynamometer: Pull in Pounds: Average	Dynamometer: Pull in Pounds: Maximum	Dynamometer: Pull in Pounds: Minimum	Cut-off, Per Cent. of Stroke: High Pressure Cylinder: Right Side: Head End	Cut-off: H.P. Cyl.: Right Side: Crank End	Cut-off: H.P. Cyl.: Left Side: Head End	Cut-off: H.P. Cyl.: Left Side: Crank End	Cut-off: Low Pressure Cylinder: Right Side: Head End	Cut-off: L.P. Cyl.: Right Side: Crank End	Cut-off: L.P. Cyl.: Left Side: Head End	Cut-off: L.P. Cyl.: Left Side: Crank End	Release, Per Cent. of Stroke: High Pressure Cylinder: Right Side: Head End	Release: H.P. Cyl.: Right Side: Crank End	Release: H.P. Cyl.: Left Side: Head End	Release: H.P. Cyl.: Left Side: Crank End
		259	260	261	262	263	264	265	266	267	268	269	270	271	272	273	274	275	276	277	278	279
3111	120-20-F	30376		0			30376	6678	6805	6465	16.2	18.9	19.0	19.0					53.4	56.2	57.2	53.9
3112	120-30-F	36170		0			36170	9516	9728	8880	22.0	27.0	25.9	26.0					58.2	59.4	61.5	59.8
3137	120-40-F	42739		0			42739	13136	13275	12981	34.4	34.3	-	-					67.0	63.7	-	-
3121	160-30-F	41027		0			41027	10057	10224	9728	23.7	27.2	26.3	28.5					61.7	60.9	63.7	60.0
3113	160-35-F	47571		0			47571	11025	11126	10621	30.1	31.1	32.6	32.0					69.5	64.0	66.3	59.4
3114	160-45-F	44927		0			44927	13565	13719	13177	38.1	42.1	41.1	43.2					70.4	69.9	70.0	68.5
3133	160-50-F	30691		0			30691	15114	15418	14922	42.9	42.7	-	-					70.1	70.2	-	-
3136	200-20-F	38631		0			38631	7407	7585	7147	20.2	22.1	-	-					54.8	58.0	-	-
3115	200-35-F	53847		0			53847	9953	10224	9279	30.2	33.5	33.1	33.8					63.5	64.0	63.8	63.5
3135	200-35-F	25650		0			25650	10763	10819	10720	29.6	32.6	-	-					63.5	64.3	-	-
3134	200-35-F	26232		0			26232	10628	10770	10373	31.4	31.6	-	-					66.3	63.3	-	-
3124	200-45-F	49327		0			49327	12357	12686	11657	41.5	40.4	40.7	43.2					68.3	68.8	71.7	68.9
3117	240-20-F	42087		0			42087	6409	6611	5974	20.0	22.3	24.0	24.9					57.1	58.5	59.5	57.3
3116	240-35-F	43417		0			43417	8965	9030	8880	31.8	34.0	32.9	34.9					62.5	62.4	63.9	65.2
3109	240-45-F	34737		0			34737	10274	10621	9778	41.0	41.6	42.1	43.8					68.1	69.8	72.6	72.0
3139	240-45-F	33970		0			33970	10536	11018	9977	42.1	41.6	-	-					69.5	69.6	-	-
3119	280-20-F	34743		0			34743	5503	5726	5378	26.1	25.2	24.7	26.8					57.7	57.6	61.5	59.9
3122	280-30-F	26629		0			26629	7090	7734	6708	28.1	31.4	31.1	33.9					63.2	64.7	66.0	65.4
3125	280-35-F	31638		0			31638	8034	8232	7934	33.1	33.9	35.1	35.3					64.1	63.2	69.2	67.1
3126	320-20-F	25082		0			25082	4620	4779	4476	19.4	19.6	20.7	25.1					56.6	61.6	63.5	64.6
3128	320-25-F	28079		0			28079	5965	6756	5478	24.0	27.6	-	-					59.5	63.3	-	-
3127	320-30-F	29743		0			29743	5951	6903	5529	29.8	29.5	30.8	32.9					62.4	65.4	64.2	64.7
3142	360-35-F	13984		0			13984	5676	6417	5230	30.5	32.1	-	-					59.1	65.0	-	-
3143	360-35-F	14704					14704	5316	5726	4930	30.9	32.3	-	-					63.1	62.9	-	-

(M. P. Special.) TEST OF LOCOMOTIVE No. 518 TYPE 4-4-2 CLASS E3sd (Sheet No. 7)

SUMMARY OF AVERAGE RESULTS.

Test Number	Laboratory Designation	Events of Stroke from Indicator Cards — Release, per cent. of stroke — Low Pressure Cylinder — Right Side — Head End	Crank End	Left Side — Head End	Crank End	Beginning of Compression, per cent. of stroke — High Pressure Cylinder — Right Side — Head End	Crank End	Left Side — Head End	Crank End	Low Pressure Cylinder — Right Side — Head End	Crank End	Left Side — Head End	Crank End	Pressure from Indicator Cards — Initial Pressures, pounds per square inch — High Pressure Cylinder — Right Side — Head End	Crank End	Left Side — Head End	Crank End	Low Pressure Cylinder — Right Side — Head End	Crank End	Left Side — Head End	Crank End	Factor of Evaporation
		280	281	282	283	284	285	286	287	288	289	290	291	292	293	294	295	296	297	298	299	300
3111	120-20-F													204.8	195.8	191.8	197.0					1.2954
3112	120-30-F													200.9	199.6	189.6	194.8					1.3062
3137	120-40-F													199.7	202.1	-	-					1.3330
3121	160-30-F													194.1	197.6	191.8	188.0					1.3384
3113	160-35-F													197.8	196.5	186.8	192.2					1.3181
3114	160-45-F													193.7	191.2	183.5	192.0					1.3258
3133	160-50-F													191.1	191.4	-	-					1.3443
3136	200-20-F													195.3	197.9	-	-					1.3349
3115	200-35-F													193.8	190.0	185.2	192.6					1.3283
3135	200-35-F													194.9	196.3	-	-					1.3501
3134	200-35-F													194.3	194.0	-	-					1.3463
3124	200-45-F													184.9	186.4	180.9	184.5					1.3518
3117	240-20-F													198.8	199.0	187.9	202.3					1.3434
3116	240-35-F													189.3	187.8	177.2	192.6					1.3442
3109	240-45-F													169.4	168.3	161.4	171.1					1.3310
3139	240-45-F													170.0	172.3	-	-					1.3612
3119	280-20-F													194.1	185.6	185.0	191.9					1.3505
3122	280-30-F													174.7	175.6	171.3	177.6					1.3508
3125	280-35-F													178.7	179.6	177.9	180.9					1.3485
3126	320-20-F													190.0	189.0	188.7	194.9					1.3415
3128	320-25-F													188.6	191.3	-	-					1.3484
3127	320-30-F													189.0	185.8	186.8	187.0					1.3489
3142	360-25-F													190.8	193.5	-	-					1.3470
3143	360-25-F													-	198.0	-	-					1.3469

(M. P. Special.) TEST OF LOCOMOTIVE No. 318 TYPE 4-4-2 CLASS E3sd (Sheet No. 8)

SUMMARY OF AVERAGE RESULTS.

Test Number	Laboratory Designation	PRESSURES FROM INDICATOR CARDS																				
		STEAM CHEST PRESSURES, POUNDS PER SQUARE INCH					PRESSURES AT CUT-OFF, POUNDS PER SQUARE INCH								PRESSURES AT RELEASE, POUNDS PER SQUARE INCH							
		HIGH PRESSURE		LOW PRESSURE			HIGH PRESSURE CYLINDER				LOW PRESSURE CYLINDER				HIGH PRESSURE CYLINDER				LOW PRESSURE CYLINDER			
							RIGHT SIDE		LEFT SIDE		RIGHT SIDE		LEFT SIDE		RIGHT SIDE		LEFT SIDE		RIGHT SIDE		LEFT SIDE	
		Right Side	Left Side	Right Side	Left Side		Head End	Crank End	Head End	Crank End	Head End	Crank End	Head End	Crank End	Head End	Crank End	Head End	Crank End	Head End	Crank End	Head End	Crank End
		301	302	303	304	305	306	307	308	309	310	311	312	313	314	315	316	317	318	319	320	321
3111	120-20-F		197.7				147.4	149.5	147.5	152.7					46.9	51.5	47.3	55.5				
3112	120-30-F		200.3				152.8	153.8	150.8	152.8					56.4	68.1	57.2	63.9				
3137	120-40-F		-				136.5	153.2	-	-					63.4	77.0	-	-				
3121	160-30-F		196.4				127.1	145.1	134.8	134.4					49.3	59.5	51.4	60.1				
3113	160-35-F		198.1				129.6	142.4	133.3	142.4					61.7	62.8	56.8	72.2				
3114	160-45-F		187.5				140.4	140.4	142.0	146.5					67.2	77.0	56.3	84.7				
3133	160-50-F		-				137.9	146.4	-	-					79.1	82.3	-	-				
3136	200-20-F		-				114.7	123.6	-	-					41.7	44.1	-	-				
3115	200-35-F		194.7				120.2	127.2	122.8	126.8					53.1	60.5	57.8	63.7				
3135	200-35-F		-				123.6	128.0	-	-					54.1	57.9	-	-				
3134	200-35-F		-				123.3	131.6	-	-					53.3	59.0	-	-				
3124	200-45-F		182.4				129.9	137.8	134.2	133.5					70.8	74.1	69.8	75.8				
3117	240-20-F		194.8				120.0	126.2	114.0	118.2					40.1	34.4	40.5	46.8				
3116	240-35-F		189.9				115.4	121.3	119.4	116.9					54.6	61.5	55.2	57.0				
3109	240-45-F		175.1				112.1	117.7	116.0	116.6					61.7	63.1	59.4	65.9				
3139	240-45-F		-				104.7	221.6	-	-					64.3	65.4	-	-				
3119	280-20-F		193.0				104.3	116.2	111.9	113.9					38.0	44.5	39.1	43.7				
3122	280-30-F		179.9				102.0	114.1	109.4	108.3					41.6	50.3	43.4	49.3				
3125	280-35-F		186.9				109.9	117.3	115.6	118.9					49.3	58.0	50.6	54.4				
3126	320-20-F		190.1				108.6	134.6	125.4	120.7					37.9	40.4	38.0	41.4				
3128	320-25-F		-				107.7	120.0	-	-					42.0	42.4	-	-				
3127	320-30-F		163.8				98.2	124.0	109.8	111.3					43.5	45.0	46.0	49.5				
3142	360-25-F		-				89.0	104.8	-	-					38.8	41.0	-	-				
3143	360-25-F		-				98.0	108.0	-	-					40.0	43.0	-	-				

(M. P. Special.) TEST OF LOCOMOTIVE No. 318 TYPE 4-4-2 CLASS E3sd (Sheet No. 9.)

SUMMARY OF AVERAGE RESULTS. | SUMMARY OF AVERAGE RESULTS, BOILER.

Test	Laboratory	PRESSURES FROM INDICATOR CARDS																DRY COAL FIRED		EVAPORATION, POUNDS			
		PRESSURES AT BEGINNING OF COMPRESSION, POUNDS PER SQUARE INCH								LEAST BACK PRESSURE, POUNDS PER SQUARE INCH										STEAM PER HOUR			
		HIGH PRESSURE CYLINDER				LOW PRESSURE CYLINDER				HIGH PRESSURE CYLINDER				LOW PRESSURE CYLINDER									
		RIGHT SIDE		LEFT SIDE		RIGHT SIDE		LEFT SIDE		RIGHT SIDE		LEFT SIDE		RIGHT SIDE		LEFT SIDE							
Number	Designation	Head End	Crank End	Head End	Crank End	Head End	Crank End	Head End	Crank End	Head End	Crank End	Head End	Crank End	Head End	Crank End	Head End	Crank End	Per Hour	Per Square Foot of Grate Surface	Moist		Per Sq. Ft. of Heating Surface	Steam Per Pound of Dry Coal Fired
		322	323	324	325	326	327	328	329	330	331	332	333	334	335	336	337	338	339	340	341	342	343
3111	120-20-F									1.4	1.8	2.1	2.2					1706	31.19	15188	15133	6.53	8.87
3112	120-30-F									1.2	6.6	3.5	1.9					2240	40.95	18085	18016	7.56	8.04
3137	120-40-F									2.5	3.2	-	-					2942	53.78	21370	21302	8.94	7.24
3121	160-30-F									4.3	3.8	2.8	5.2					2527	46.20	20514	20434	8.58	8.09
3113	160-35-F									4.8	5.0	6.0	6.2					2950	53.93	23786	23698	9.95	8.03
3114	160-45-F									5.9	6.9	8.3	9.6					4888	89.36	29951	29843	12.53	6.11
3133	160-50-F									7.6	6.7	-	-					5501	100.57	30691	30559	12.83	5.56
3136	200-20-F									1.6	1.8	-	-					2452	44.83	19316	19254	8.08	7.85
3115	200-35-F									5.2	7.2	8.0	8.2					4042	73.89	26924	26832	11.27	6.64
3135	200-35-F									5.1	4.0	-	-					3663	66.97	25650	25563	10.73	6.98
3134	200-35-F									6.4	5.4	-	-					4477	81.85	26232	26143	10.98	5.84
3124	200-45-F									11.5	10.7	11.1	12.7					5491	100.38	32885	32760	13..6	5.97
3117	240-20-F									2.2	5.2	5.2	6.1					2724	49.80	21044	20972	8.81	7.70
3116	240-35-F									7.0	7.6	8.9	9.8					4395	80.35	28945	28835	12.11	6.56
3109	240-45-F									11.9	11.3	12.1	15.4					5703	104.26	34737	34615	14.53	6.07
3139	240-45-F									12.7	10.9	-	-					5977	109.27	33970	33851	14.21	5.66
3119	280-20-F									2.4	4.5	6.0	7.0					3219	58.85	23162	23079	9.69	7.17
3122	280-30-F									7.4	10.6	7.6	9.1					4314	78.87	26629	26530	11.14	6.15
3125	280-35-F									9.4	10.4	10.9	11.9					4916	89.87	31638	31518	13.23	6.41
3126	320-20-F									4.7	5.6	5.9	7.7					3777	69.05	25082	24994	10.50	6.62
3128	320-25-F									7.7	6.6	-	-					4108	75.11	28079	27967	11.74	6.81
3127	320-30-F									7.3	7.6	9.2	9.8					5616	102.67	29743	29627	12.44	5.28
3142	360-25-F									7.3	8.5	-	-					5138	93.93	27968	27876	11.71	5.43
3143	360-25-F									8.0	9.0	-	-					5444	99.52	29408	29299	12.30	5.38

(M. P. Special.) TEST OF LOCOMOTIVE No. 318 TYPE 4-4-2 CLASS E3sd (Sheet No. 10)

SUMMARY OF AVERAGE RESULTS, BOILER.

SUMMARY OF AVERAGE RESULTS, ENGINES.

Test Number	Laboratory Designation	Equiv't Evap'n from and at 212° F., lbs. Per Hour	Per Hour, Per Square Foot of Heating Surface	Per Pound of Coal as Fired	Per Pound of Dry Coal as Fired	Per Pound of Combustible	Boiler Horse Power	Efficiency of Boiler	Mean Effective Pressure, Pounds per Square Inch: High Pressure Cylinder, Right Side, Head End	H.P. Right Side, Crank End	H.P. Left Side, Head End	H.P. Left Side, Crank End	Low Pressure Cylinder, Right Side, Head End	L.P. Right Side, Crank End	L.P. Left Side, Head End	L.P. Left Side, Crank End	Receiver Pressure, Right Side	Receiver Pressure, Left Side	Number of Expansions: Right Side, Head End	Right Side, Crank End	Left Side, Head End	Left Side, Crank End
		344	345	346	347	348	349	350	351	352	353	354	355	356	357	358	359	360	361	362	363	364
3111	120-20-F	19603	8.23	11.30	11.49	12.27	568.2	77.20	57.10	64.38	64.78	65.47							2.60	2.44	2.46	2.34
3112	120-30-F	23532	9.88	10.33	10.51	11.22	682.1	70.62	72.31	82.70	79.26	84.34							2.24	1.95	2.08	2.02
3137	120-40-F	28396	11.92	9.47	9.65	10.28	823.1	64.22	91.98	98.12	95.66	102.04							1.78	1.71	-	-
3121	160-30-F	27349	11.48	10.64	10.82	11.74	792.7	73.60	69.49	79.46	74.66	78.41							2.24	2.00	2.12	1.89
3113	160-35-F	31236	13.12	10.41	10.59	11.31	905.4	71.16	78.34	84.41	81.52	87.84							1.80	1.86	1.85	1.70
3114	160-45-F	39566	16.61	7.96	8.09	8.64	1146.8	54.35	95.62	100.64	98.81	106.34							1.71	1.56	1.60	1.50
3133	160-50-F	41080	17.25	7.32	7.47	7.91	1190.7	49.71	102.06	106.23	106.14	110.48							1.55	1.41	-	-
3136	200-20-F	25702	10.79	10.28	10.48	11.16	745.0	69.75	54.27	56.60	56.44	58.86							2.27	2.07	-	-
3115	200-35-F	35641	14.97	8.67	8.82	9.42	1033.1	59.26	72.15	80.55	77.93	82.63							1.89	1.75	1.76	1.73
3135	200-35-F	34513	14.49	9.24	9.42	10.03	1000.4	62.69	73.52	81.18	76.46	84.43							1.94	1.80	-	-
3134	200-35-F	35196	14.78	7.71	7.86	8.37	1020.2	52.31	77.08	79.63	80.16	82.82							1.90	1.80	-	-
3124	200-45-F	44285	18.60	7.93	8.07	8.75	1283.6	54.89	90.87	91.77	89.33	96.05							1.55	1.60	1.65	1.52
3117	240-20-F	28174	11.83	10.17	10.34	11.22	816.6	70.33	50.99	55.83	56.67	58.21							2.38	2.00	2.16	2.00
3116	240-35-F	38760	16.28	8.67	8.82	9.56	1123.5	60.00	69.99	73.82	70.40	76.33							1.67	1.61	1.77	1.58
3109	240-45-F	46073	19.35	7.94	8.08	8.63	1335.4	54.29	75.35	77.72	77.83	82.79							1.56	1.43	1.63	1.55
3139	240-45-F	46078	19.35	7.56	7.71	8.20	1335.6	15.31	78.31	81.95	81.44	85.23							1.55	1.57	-	-
3119	280-20-F	31168	13.09	9.52	9.68	10.50	903.4	65.85	50.88	57.94	54.19	58.64							1.96	2.00	2.20	1.97
3122	280-30-F	35837	15.05	8.17	8.31	9.01	1038.7	56.53	54.22	63.10	60.99	65.98							2.00	1.85	1.92	1.77
3125	280-35-F	42502	17.85	8.50	8.65	9.38	1231.9	58.84	61.18	68.39	66.96	71.97							1.77	1.71	1.81	1.75
3126	320-20-F	33529	14.08	8.73	8.88	9.63	971.9	60.40	45.53	52.12	51.21	56.52							2.41	2.58	2.55	2.23
3128	320-25-F	37711	15.83	9.00	9.18	9.72	1093.1	61.10	49.64	57.16	51.62	59.45							2.16	2.03	-	-
3127	320-30-F	39964	16.78	6.98	7.12	7.53	1158.4	47.39	52.59	60.51	58.42	62.98							1.89	1.98	1.88	1.80
3142	360-25-F	37549	15.77	7.17	7.31	7.78	1088.4	48.65	43.83	53.22	45.58	55.35							1.77	1.84	-	-
3143	360-25-F	39463	16.57	7.12	7.25	7.79	1143.9	48.38	48.49	52.62	50.43	54.72							1.84	1.78	-	-

(M. P. Special.) TEST OF LOCOMOTIVE No. 318 TYPE 4-4-2 CLASS E3sd (SHEET No. 11)

SUMMARY OF AVERAGE RESULTS, ENGINES.

Test Number	Laboratory Designation	INDICATED HORSE POWER — HIGH PRESSURE CYLINDER — RIGHT SIDE — Head End	Right Side — Crank End	Left Side — Head End	Left Side — Crank End	LOW PRESSURE CYLINDER — RIGHT SIDE — Head End	Right Side — Crank End	Left Side — Head End	Left Side — Crank End	DIVISION OF POWER — HIGH PRESSURE CYLINDER — Right Side	Left Side	LOW PRESSURE CYLINDER — Right Side	Left Side	TOTAL — Right Side	Left Side	Total i.h.p.	CONSUMED PER I. H. P., PER HOUR — Dry Coal, Pounds	Steam, Pounds	B. T. U.	LOCOMOTIVE — Dynamometer Horse Power	POUNDS PER D. H. P., PER HOUR — Of Dry Coal	Of Steam	B. T. U. Per D. H. P. Per Hour
		368	368	367	388	369	370	371	372	373	374	373	376	377	378	379	380	381	382	383	384	388	386
3111	120-20-F	173.83	189.82	193.64	189.58									363.65	363.22	746.87	2.28	19.91	32928	496.7	3.42	29.82	49392
3112	120-30-F	220.14	243.83	236.93	244.21									463.97	781.14	945.11	2.37	18.86	34228	710.6	3.15	25.09	45492
3137	120-40-F	280.02	289.30	291.22	300.87									569.32	592.09	1161.4	2.53	18.01	36890	980.9	3.00	21.33	43743
3121	160-30-F	282.08	311.55	297.57	302.72									593.63	600.29	1193.9	2.12	16.96	30244	1001.4	2.52	20.22	35950
3113	160-35-F	318.00	331.84	324.91	339.06									649.84	663.97	1313.8	2.25	17.83	32495	1097.7	2.69	21.34	38849
3114	160-45-F	388.14	395.63	393.82	410.56									783.77	804.48	1588.2	3.08	18.62	44481	1350.6	3.62	21.89	52280
3133	160-50-F	414.29	417.62	430.86	434.32									831.91	865.18	1697.1	3.24	17.79	47242	1504.9	3.66	20.06	53366
3136	200-20-F	275.36	278.14	286.37	289.27									553.50	575.64	1129.14	2.17	16.74	31641	921.9	2.66	20.50	36765
3115	200-35-F	366.08	395.82	388.24	398.78									761.90	787.02	1548.9	2.61	17.20	37694	1238.8	3.26	21.51	47081
3135	200-35-F	373.04	398.92	387.96	414.88									771.96	802.84	1574.8	2.33	16.09	33474	1339.6	2.73	16.92	39806
3134	200-35-F	391.10	391.30	406.74	406.95									782.40	813.70	1596.1	2.80	16.24	40827	1322.8	3.38	19.59	49284
3124	200-45-F	461.08	450.96	445.04	463.54									912.04	908.58	1820.6	3.02	17.77	40383	1538.0	3.57	21.04	50930
3117	240-20-F	310.46	329.21	338.78	337.10									639.67	675.88	1315.6	2.07	15.68	29531	957.2	2.85	21.55	40658
3116	240-35-F	426.14	435.34	420.89	442.03									861.48	862.92	1724.4	2.55	16.55	36378	1338.9	3.28	21.32	46792
3109	240-45-F	458.78	458.30	465.29	479.45									917.08	944.74	1861.6	3.06	18.46	44193	1534.4	3.72	22.39	53721
3139	240-45-F	476.81	483.24	495.88	502.57									960.05	998.45	1958.50	3.05	17.17	44472	1573.6	3.80	31.27	55408
3119	280-20-F	361.42	398.61	377.97	396.20									760.03	774.17	1534.2	2.10	14.78	29959	958.9	3.36	23.65	47934
3122	280-30-F	385.17	434.11	425.40	445.79									819.28	871.19	1690.5	2.55	15.56	36378	1235.4	3.49	21.30	49788
3125	280-35-F	434.59	470.48	467.04	486.25									905.07	953.29	1858.4	2.65	16.71	37805	1399.9	3.51	22.18	50074
3126	320-20-F	369.63	409.79	408.19	436.42									779.42	844.61	1624.03	2.33	14.91	33240	920.0	4.11	26.31	58633
3128	320-25-F	403.01	449.41	413.13	467.39									852.42	886.52	1738.9	2.36	15.89	34411	1187.8	3.46	22.97	50450
3127	320-30-F	426.94	475.74	465.76	486.30									902.68	952.06	1854.7	3.03	15.81	44180	1185.1	4.74	24.74	69114
3142	360-25-F	400.32	470.74	416.33	489.57									871.06	905.90	1776.96	2.89	15.50	42139	1271.6	4.04	21.66	58907
3143	360-25-F	442.87	465.44	460.58	484.06									908.31	944.64	1852.95	2.94	15.46	42751	1190.9	4.57	24.06	66452

(M. P. Special.) TEST OF LOCOMOTIVE No. 518 TYPE 4-4-2 CLASS E3sd (SHEET No 12.)

SUMMARY OF AVERAGE RESULTS, LOCOMOTIVE.

Test Number	Laboratory Designation	LOCOMOTIVE: Per One Million Foot Pounds at Draw-Bar: Dry Coal, Pounds	Per One Million Foot Pounds at Draw-Bar: Dry Steam, Pounds	Per One Million Foot Pounds at Draw-Bar: B. T. U.	I. H. P. per Square Foot of: Heating Surface	I. H. P. per Square Foot of: Grate Surface	D. H. P. per Square Foot of: Heating Surface	D. H. P. per Square Foot of: Grate Surface	Tractive Power Based on M. E. P., Pounds	Machine Friction of Locomotive, in Terms of: Horse Power	Machine Friction of Locomotive, in Terms of: M. E. P., Pounds	Machine Friction of Locomotive, in Terms of: Draw-Bar Pull, Pounds	Machine Efficiency of Locomotive, Per Cent.	Efficiency of Locomotive, Per Cent.	RATIOS: Total Weight of Locomotive to Maximum I. H. P.	Total Heating Surface to Maximum I. H. P.						
		387	388	389	390	391	392	393	394	395	396	397	398	399	400	401	402	403	404	405	406	407
3111	120-20-F	1.73	15.07	24985	0.31	13.65	0.209	9.12	10002	248.2	20.84	3324	66.77	5.15								
3112	120-30-F	1.59	12.67	22963	0.40	17.28	0.298	12.99	12657	234.5	19.74	3140	75.19	5.59								
3137	120-40-F	1.51	10.77	22017	0.49	21.23	0.412	17.93	15553	180.5	15.20	2417	84.46	5.82								
3121	160-30-F	1.27	10.21	18118	0.50	21.83	0.420	18.31	11992	192.5	12.16	1933	83.88	7.08								
3113	160-35-F	1.36	10.78	19641	0.55	24.02	0.461	20.07	13196	216.1	13.65	2170	83.55	6.55								
3114	160-45-F	1.83	11.06	26429	0.67	29.03	0.567	24.69	15951	237.6	15.00	2386	85.04	4.87								
3133	160-50-F	1.85	10.13	26975	0.71	31.03	0.632	27.51	17045	192.2	12.14	1930	88.67	4.77								
3136	200-20-F	1.34	10.36	19539	0.47	20.64	0.387	16.85	9073	207.2	10.47	1665	81.65	6.56								
3115	200-35-F	1.65	10.86	23829	0.65	28.32	0.520	22.65	12446	310.1	15.66	2492	79.98	5.41								
3135	200-35-F	1.38	9.56	20122	0.66	28.79	0.562	24.49	12654	235.2	11.88	1890	85.06	6.59								
3134	200-35-F	1.71	9.90	24934	0.67	29.18	0.555	24.18	12825	273.3	13.81	2196	82.88	5.16								
3124	200-45-F	1.80	10.62	25679	0.76	33.28	0.646	28.12	14629	282.6	14.28	2271	84.48	5.00								
3117	240-20-F	1.44	10.88	20543	0.55	24.05	0.402	17.50	8609	358.4	15.09	2400	72.76	5.26								
3116	240-35-F	1.66	10.77	23682	0.72	31.52	0.562	24.48	11546	385.5	16.23	2581	77.64	5.44								
3109	240-45-F	1.88	11.31	27151	0.78	34.04	0.644	28.05	12467	327.4	13.78	2192	82.41	4.74								
3139	240-45-F	1.92	10.79	27996	0.82	35.80	0.661	28.77	13117	384.9	16.20	2581	80.31	4.59								
3119	280-20-F	1.70	11.95	24252	0.64	28.05	0.403	17.53	8805	575.3	20.76	3302	62.50	5.31								
3122	280-30-F	1.76	10.76	25108	0.71	30.90	0.519	22.59	9728	455.1	16.42	2612	73.08	5.11								
3125	280-35-F	1.77	11.20	25251	0.78	33.97	0.588	25.59	10666	458.5	16.54	2631	75.33	5.08								
3126	320-20-F	2.07	13.29	29531	0.68	29.69	0.386	16.82	8156	704.0	22.23	3535	56.65	4.34								
3128	320-25-F	1.75	11.60	25517	0.73	31.79	0.499	21.71	8733	551.1	17.40	2768	68.31	5.04								
3127	320-30-F	2.39	12.50	34849	0.78	33.91	0.498	21.67	9314	669.6	21.14	3363	63.90	3.68								
3142	360-25-F	2.04	10.94	29745	0.75	32.49	0.534	23.25	7932	505.4	14.18	2256	71.56	4.32								
3143	360-25-F	2.31	12.15	33590	0.78	33.48	0.500	21.77	8271	662.1	18.58	2956	64.27	3.83								

Tests of Class E2d Saturated Steam Locomotive No. 3162.

On page 139 are shown boiler tests from one to three hours in length.

On page 140 are shown indicated horse-power tests where the length of test was too short for reliable boiler or coal results and they are not recorded.

(M. P. Special.) (Sheet No. 1.)

PENNSYLVANIA RAILROAD COMPANY.

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY.
NORTHERN CENTRAL RAILWAY COMPANY.
WEST JERSEY & SEASHORE RAILROAD COMPANY.

TEST DEPARTMENT.
LOCOMOTIVE TESTING PLANT.

TEST OF LOCOMOTIVE No. 3162 TYPE 4-4-2 CLASS E2d BUILT AT Juniata Shops, Altoona - Penna., 1906

Atlantic Type Locomotive using Saturated Steam PRESENTED FOR TEST BY Pennsylvania Railroad Company.

TESTED AT Altoona Locomotive Testing Plant. TESTED Dec. 1907 and Jan. 1908 TEST Nos. 1101 TO 1135 SERIES No. 1100

DESCRIPTION, DIMENSIONS AND PROPORTIONS.

	DRIVING WHEELS.	
1	Number of pairs	2
2	Approximate diameter, inches	80
	MEASURED CIRCUMFERENCE, FEET.	
3	Right, No. 1	20.47
4	" " 2	20.47
5	" " 3	-
6	" " 4	-
7	" " 5	-
8	Left, " 1	20.47
9	" " 2	20.47
10	" " 3	-
11	" " 4	-
12	" " 5	-
13	Average	20.47
	ENGINE TRUCK WHEELS.	
14	Number	4
15	Diameter, inches	36
	TRAILING WHEELS.	
16	Diameter, inches	50
	WHEEL BASE, FEET.	
17	Driving wheel base	7.42
18	Total wheel base	30.78
19	Gauge of wheels, in inches	56.13

DESCRIPTIONS, DIMENSIONS AND PROPORTIONS.

	VALVES.	
82	Type	Piston
83	Design	American Balance Valve Company
84	Per cent. of balanced to total area	100
85	Type of link motion	Walschaerts
	GREATEST VALVE TRAVEL, INCHES.	
86	High pressure, right	6.83
87	" " left	6.83
88	Low " right	-
89	" " left	-
	STEAM LAP OF VALVE, INCHES.	
90	High Pressure, right, head end	1.38
91	" " " crank "	1.38
92	" " left, head "	1.38
93	" " " crank "	1.33
94	Low " right, head "	-
95	" " " crank "	-
96	" " left, head "	-
97	" " " crank "	-
	EXHAUST LAP OF VALVE, INCHES.	
98	High Pressure, right, head end. Neg.	0.29
99	" " " crank " "	0.36
100	" " left, head "	0.26
101	" " " crank "	0.31
102	Low " right, head "	-
103	" " " crank "	-
104	" " left, head "	-
105	" " " crank "	-
	MISCELLANEOUS.	
106	Cylinder lagging material	Magnesia
107	" jacket "	Sheet Iron
108		
109		

WEIGHT OF ENGINE WITH WATER AT 2ND GAUGE COCK AND NORMAL FIRE, IN POUNDS.

20	On truck	32833
21	" 1st drivers	61400
22	" 2nd "	60467
23	" 3rd "	-
24	" 4th "	-
25	" 5th "	-
26	" trailers	30233
27	Total	184933
28	" on drivers	121867
	CYLINDERS.	
29	High pressure, number	2
30	Low " "	—
31	Arrangement	Outside
	DIAMETER, INCHES.	
32	High pressure, right	20.715
33	" " left	20.749
34	Low " right	-
35	" " left	-
	STROKE OF PISTON, FEET.	
36	High pressure, right	2.161
37	" " left	2.165
38	Low " right	-
39	" " left	-
110		
111		
112		
	BOILER.	
113	Type	Belpaire Wide Firebox
114	Outside diameter, 1st ring, inches	67
	TUBES.	
115	Number	315
116	Outside diameter, inches	2
117	Thickness, inches	0.125
118	Length between tube sheets, inches	180.72
119	Total fire area, square feet	5.26
120	Serve Tubes, number of ribs	-
121	" " sq. in. of inside surface in one in. of length	-
122		
123		
124	Boiler Pressure.	205
	NO SUPERHEATER.	
125	Number of tubes	-
126	Outside diameter, inches	-
127	Thickness, inches	-
128	Length of tubes, inches	-
129		
130		
131		
	FIRE BOX (SIZE INSIDE, INCHES.)	
132	Length	114.24
133	Width	67.32
134	Depth, front end	60.72
135	" back "	56.40
136	Volume, cubic feet	228.43
137		
138		
139		
140		

CLEARANCE PER CENT. OF PISTON DISPLACEMENT.

40	H. P., right, head end	16.5
41	" " crank "	16.8
42	" left, head "	16.1
43	" " crank "	15.9
44	L. P., right, head "	-
45	" " crank "	-
46	" left, head "	-
47	" " crank "	-
	RECEIVER, CUBIC FEET.	
48	Volume, right side	-
49	" left "	-
	STEAM PORTS, INCHES. (For piston valves the length equals the circumference of inside of bushing minus the sum of the widths of bridges.)	
50	H. P. admission, right, head end, length	35.43
51	" " " " " width	2.00
52	" " " crank " length	35.82
53	" " " " " width	2.07
54	" " left, head " length	35.61
55	" " " " " width	2.00
56	" " " crank " length	35.49
57	" " " " " width	2.05
58	L. P. " right, head " length	-
59	" " " " " width	-
	FIRE DOORS.	
141	Number	One
142	Area, square feet	1.59
143		
	GRATES.	
144	Style	Rocking Wide Bar & Rocking finger
145	Total area, square feet	55.3
146	" " dead grates, square feet Finger grate	6
147	Width of air spaces, inches	
	AIR INLET AREAS, SQUARE FEET.	
148	Through firebox sides	0
149	" grates	15.00
150	" fire doors	0.07
151	Total air inlets, (148), (149) and (150)	15.07
152	Ratio " " (149) to grate area (145)	0.27
153	" " " (151) to " " (145)	0.27
	HEATING SURFACE, SQUARE FEET.	
154	Of the tubes, water side	2403.91
155	" " " fire "	2173.42
156	" " firebox, fire side	162.61
157	" " superheater, fire side	
158	Total, based on inside of firebox and inside of tubes	2336.03
159	" " " " " " " outside of tubes	2566.52
	BOILER VOLUMES With water surface at level of second gauge cock.	
160	Water space, cubic feet	230.4
161	Steam " "	118.5
	EXHAUST NOZZLE.	
162	Double or single Single Circular	
163	Size of right, inches Size Area	
164	" " left, " Diam. In. 5.625 24.85	
165	Area of right, square inches 5.75 25.97	
166	" " left, " " 6.00 28.27	
167	Total area, square inches	

60	L. P. admission, right, crank end, length	—
61	" " " " " width	—
62	" " left, head " length	—
63	" " " " " width	—
64	" " " crank " length	—
65	" " " " " width	—
66	H. P. exhaust, right, length	No Port
67	" " " width	"
68	" " left, length	"
69	" " " width	"
70	L. P. " right, length	—
71	" " " width	—
72	" " left, length	—
73	" " " width	—
	PISTON RODS, DIAMETER, INCHES.	
74	High pressure, right	3.472
75	" " left	3.475
76	Low " right	—
77	" " left	—
	TAIL RODS, DIAMETER, INCHES.	
78	High pressure, right	—
79	" " left	—
80	Low " right	—
81	" " left	—
	REVERSE LEVER.	
168	H. P. cylinder, notches forward of centre	15
169	L. P. " " " " "	-
170		
	RATIOS.	
171	Heating surface (158) to grate area (145)	42.24
172	Fire area through tubes (119) to grate area (145)	0.10
173	Firebox heating surface (156) to grate area (145)	2.94
174	Tube surface (155) to firebox heating surface (156)	13.37
175	Firebox volume (136) to grate area (145)	4.13
176		
177		
178		
	CONSTANTS	
179	For dynamometer H. P., (power developed when the speed is one M. P. H. and the pull is one pound)	0.0006203
	FOR INDICATED HORSE POWER. (power developed at one R. P. M. and one pound M. E. P.)	
180	High Pressure Cylinder, right, head end	0.02207
181	" " " " crank "	0.02145
182	" " " left, head "	0.02218
183	" " " " crank "	0.02156
184	Low " " right, head "	-
185	" " " " crank "	-
186	" " " left, head "	-
187	" " " " crank "	-
	PISTON DISPLACEMENT, CUBIC FEET.	
188	High pressure Cylinder, right, head end	5.06
189	" " " " crank "	4.92
190	" " " left, head "	5.08
191	" " " " crank "	4.94
192	Low " " right, head "	-
193	" " " " crank "	-
194	" " " left, head "	-
195	" " " " crank "	-

(M. P. Special.) TEST OF LOCOMOTIVE No. 3162 TYPE 4-4-2 CLASS 22d (SHEET No. 13)

SUMMARIZED STATEMENT OF AVERAGE RESULTS.

Test Number	Laboratory Designation	Duration of Test, Hours	Revolutions Per Minute	Equivalent Miles Per Hour	GRATES.	Position of Throttle	Boiler Pressure, Pounds Per Square Inch	EXHAUST NOZZLE.	Draft, Front of Diaphragm, Inches of Water	Dry Coal Fired Per Hour, Pounds	Dry Steam Used Per Hour, Pounds	Equivalent Pounds Water Per Pound Coal From and at 212° F.	Indicated Horse Power	Dynamometer Horse Power	Frictional Horse Power	Draw-Bar Pull, Pounds	Dry Coal Per I. H. P. Per Hour, Pounds	Dry Coal Per D. H. P. Per Hour, Pounds	Dry Steam Per I. H. P. Per Hour, Pounds	Dry Steam Per D. H. P. Per Hour, Pounds	Efficiency of Boiler	Efficiency of Locomotive
		196	193	199		203	217		222	338	341	347	379	383	395	285	380	384	381	385	350	399
1101	80-15-F	3.00	80	18.69	Wide Bar	Full	205.0	5.625	1.6	1665	13407	9.89									65.35	
1102	80-20-F	3.00	80	18.69	"	"	20[illegible].3	5.625	2.2	2011	16631	9.98									55.95	
1103	80-30-F	3.00	80	18.69	"	"	205.3	5.625	3.0	2461	19638	9.81									64.82	
1104	120-15-F	3.00	120	28.04	"	"	205.5	5.625	2.4	2117	17840	10.35									68.39	
1105	120-20-F	2.75	120	28.04	"	"	203.3	5.625	3.2	2788	22087	9.76									64.49	
1106	120-30-F	2.25	120	28.04	"	"	203.9	5.265	4.8	3386	27131	9.88									65.29	
1107	160-15-F	2.75	160	37.38	"	"	205.1	5.625	3.4	2625	21389	10.04									66.34	
1109	160-30-F	2.00	160	37.38	"	"	200.5	5.75	7.6	5397	33368	9.61									51.84	
1110	160-32-F	1.75	160	37.38	"	"	192.3	5.75	8.5	6450	35333	6.75									45.93	
1116	80-20-F	3.00	80	18.61	Finger	"	203.2	5.75	2.3	1729	15072	10.69									72.73	
1122	120-30-F	1.83	120	27.91	"	"	203.8	5.75	4.7	3013	25598	10.46									71.17	
1113	160-32-F	1.75	160	37.38	"	"	192.7	5.75	9.0	5963	35504	7.33									49.87	
1114	200-15-F	2.00	200	46.73	"	"	203.2	5.75	5.5	3636	26847	9.08									61.78	
1115	200-20-F	1.50	200	46.73	"	"	204.2	5.75	7.2	4542	32607	8.84									60.18	
1123	200-30-F	1.00	199	46.29	"	"	186.7	6.00	7.4	5606	32305	7.08									48.17	

(M. P. Special.) TEST OF LOCOMOTIVE No. 3162 TYPE 4-4-2 CLASS E2d (SHEET No. 13)

SUMMARIZED STATEMENT OF AVERAGE RESULTS.

Test Number	Laboratory Designation	Duration of Test, Hours	Revolutions Per Minute	Equivalent Miles Per Hour	Approximate Cut-Off, Per Cent. of Stroke, High Pressure Cylinder	Position of Throttle	Boiler Pressure, Pounds Per Square Inch	EXHAUST NOZZLE.	Piston Speed in Feet Per Minute	Dry Coal Fired Per Hour, Pounds	Dry Steam to Engines, Pounds per Hour	Equivalent Pounds Water Per Pound Coal From and at 212° F	Indicated Horse Power	Dynamometer Horse Power	Frictional Horse Power	Draw-Bar Pull, Pounds	Dry Coal Per I. H. P. Per Hour, Pounds	Dry Coal Per D. H. P. Per Hour, Pounds	Dry Steam Per I. H. P. Per Hour, Pounds	Dry Steam Per D. H. P. Per Hour, Pounds	Efficiency of Boiler	Efficiency of Locomotive
		198	198	199	268 to 271	203	217		200	336	214	347	379	383	395	285	380	384	381	385	350	399
1131	80-15-F	0.75	80	18.61	14.3	Full	205.4	6.00	346.0		11604		401.8	343.0	58.8	6912			28.88	33.83		-
1116	80-20-F	3.00	80	18.61	21.5	"	203.2	5.75	346.0		14814		527.8	454.5	73.3	9160			28.07	32.50		4.72
1125	80-30-F	0.50	79.8	18.56	28.3	"	204.9	6.00	345.2		17357		653.4	565.6	87.8	11427			26.56	30.69		-
1130	120-15-F	0.75	120	27.91	14.5	"	203.5	6.00	519.2		15785		617.3	501.1	116.2	6732			25.57	31.50		-
1128	120-20-F	0.75	119.8	27.87	22.8	"	204.5	6.00	518.2		20034		796.2	668.2	128.0	8992			25.60	29.98		-
1122	120-30-F	1.83	120.0	27.91	30.2	"	203.8	6.00	519.2		25555		977.7	870.7	107.0	11697			26.14	29.35		5.18
1129	160-15-F	0.50	160.1	37.24	14.8	"	203.6	6.00	692.6		18904		775.7	586.8	188.9	5909			24.37	32.22		-
1127	160-20-F	0.50	159.9	37.19	22.3	"	204.3	6.00	691.8		23512		993.6	814.1	179.5	8207			23.66	28.88		-
1124	160-30-F	0.50	160.1	37.24	29.5	"	204.4	6.00	692.6		29233		1199.5	1044.2	155.3	10515			24.37	28.00		-
1132	160-30-F	0.50	160.0	37.22	31.3	"	201.9	6.00	692.2		28520		1196.8	1003.8	193.0	10114			23.87	28.46		-
1133	160-30-F	0.50	160.0	37.22	32.0	"	202.4	6.00	692.2		29443		1194.1	999.5	194.6	10071			24.66	29.46		-
1120	160-32-F	0.50	159.9	37.19	36.8	"	204.3	6.00	691.8		33103		1323.4	1157.9	165.5	11674			25.01	28.59		-
1126	200-20-F	0.50	199.7	46.45	24.7	"	203.3	6.00	864.0		28255		1191.1	927.7	263.4	7469			23.72	30.46		-
1117	200-30-F	0.58	200.0	46.52	33.4	"	203.1	5.75	865.2		34777		1413.9	1079.3	334.6	8700			24.60	32.22		-
1123	200-30-F	1.00	199.0	46.29	32.3	"	186.7	6.00	860.8		31957		1300.7	1044.3	256.4	8460			24.57	30.60		3.34
1118	200-32-F	-	199.8	46.48	37.8	"	198.5	5.75	864.4		-		1497.4	-	-	-			-	-		-
1121	200-32-F	-	200.0	46.52	35.2	"	191.0	6.00	865.2		-		1464.9	-	-	-			-	-		-
1119	240-15-F	-	240.0	55.83	20.4	"	203.5	5.75	1038.2		-		1092.0	-	-	-			-	-		-

GRAPHICAL LOGS OF TESTS.

A graphical log is made for each test to show the conditions at each ten-minute interval, and to indicate any irregularity in the weights of coal and water during the run.

M. P. Experimental D-1

12 9 1912
8 x 10½

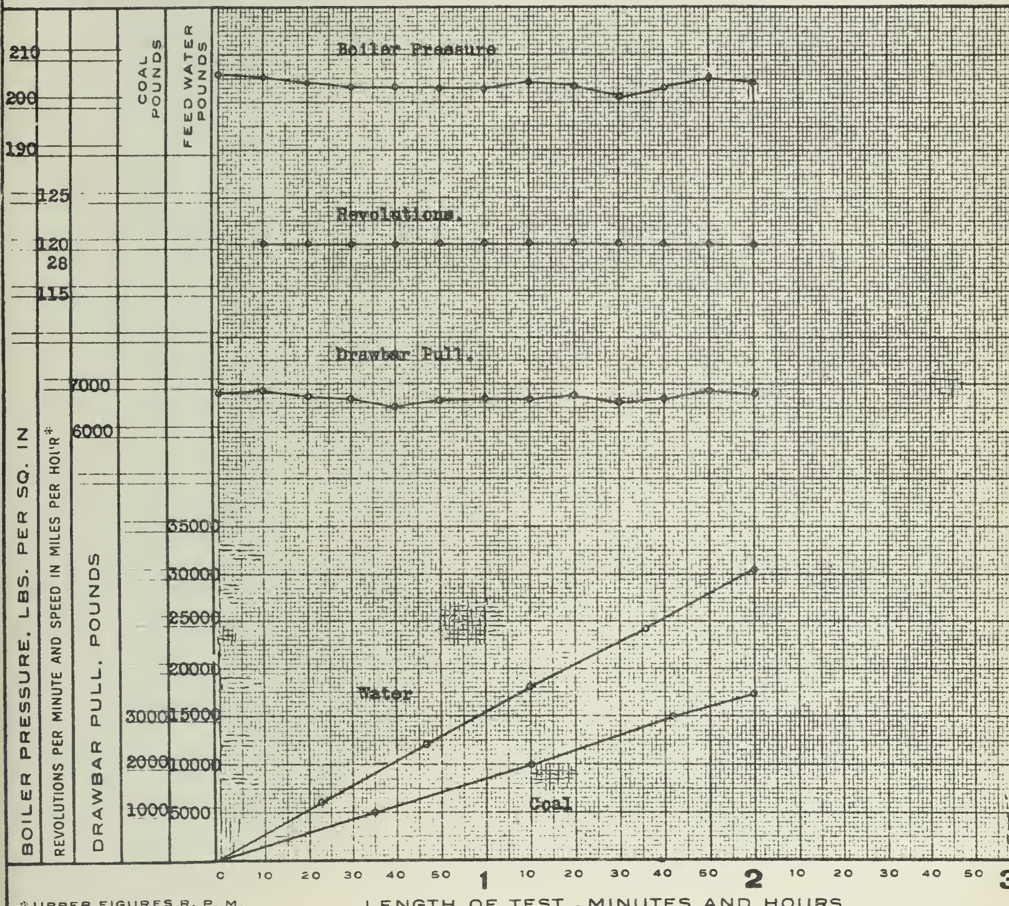
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-1116 TEST DEPARTMENT Bulletin NO. 11

GRAPHICAL LOG OF LOCOMOTIVE TEST

Tests of a Class E3sd Locomotive. ALTOONA, PA. 1-9-1913



*UPPER FIGURES R. P. M.
LOWER FIGURES APPROX. SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 4-4-2
CLASS E3sd
NUMBER 318

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
28.0	120	20	F	8.8

TEST NO. 3111

SHEET NO. P-1116

M. P. Experimental D-1

12 9 1912
8 x 10½

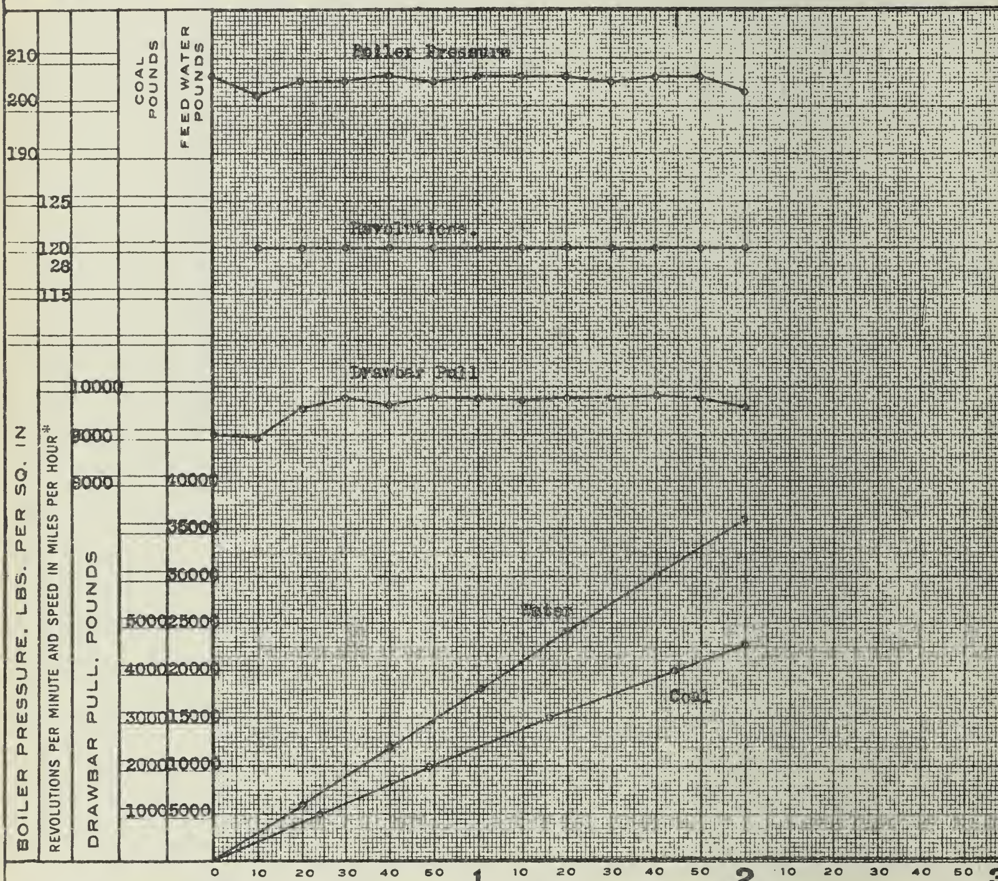
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-1117 TEST DEPARTMENT Bulletin NO. 11

GRAPHICAL LOG OF LOCOMOTIVE TEST

Tests of a Class E3sd Locomotive. ALTOONA, PA. 1-9-1913



*UPPER FIGURES R. P. M.
LOWER FIGURES APPROX.
SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 4-4-2
CLASS E3sd
NUMBER 318

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
28.0	120	30	F	7.9

TEST NO. 3112

SHEET NO. P-1117

M. P. Experimental D-1 12 9 1912 8 x 10½

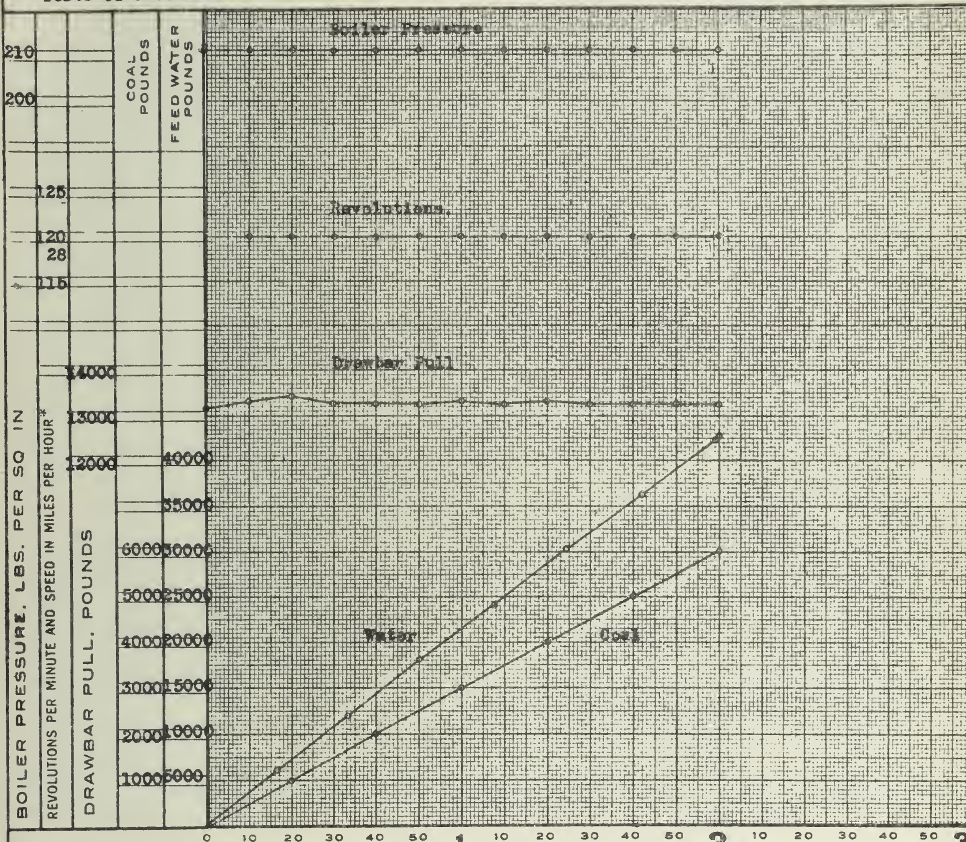
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-1118 TEST DEPARTMENT Bulletin NO. 11

GRAPHICAL LOG OF LOCOMOTIVE TEST

Tests of a Class E3sd Locomotive. ALTOONA, PA. 1-25-1913



*UPPER FIGURES R. P. M.
LOWER FIGURES APPROX. SPEED IN MILES PER HOUR

LENGTH OF TEST MINUTES AND HOURS

LOCOMOTIVE
TYPE 4-4-2
CLASS E3sd
NUMBER 318

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
28.0	120	40	F	7.1

TEST NO. 3137

SHEET NO. P-1118

M. P. Experimental D-1

12 9 1912
8 x 10½

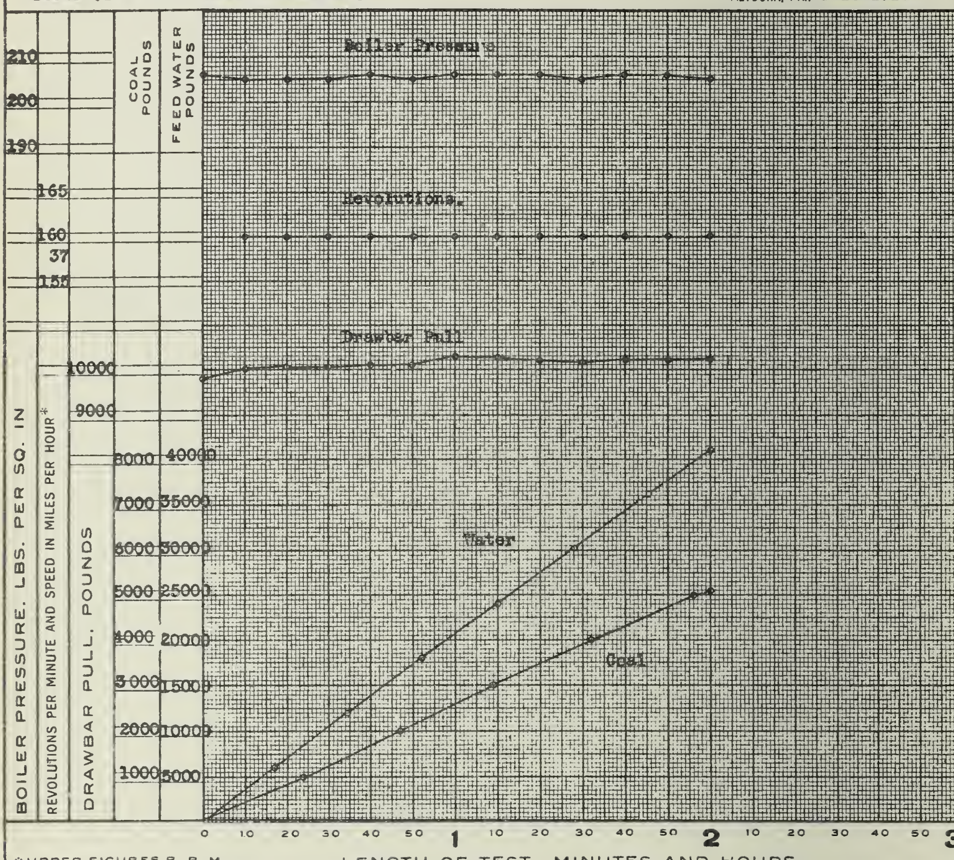
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-1119 TEST DEPARTMENT Bulletin NO 11

GRAPHICAL LOG OF LOCOMOTIVE TEST

Tests of a Class E3sd Locomotive. ALTOONA, PA., 1-16-1913



*UPPER FIGURES R. P. M.
LOWER FIGURES APPROX.
SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 4-4-2
CLASS E3sd
NUMBER 318

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
37.3	160	30	F	8.0

TEST NO. 3121

SHEET NO. P-1119

M. P. Experimental D-1

12 9 1912
8 x 10½

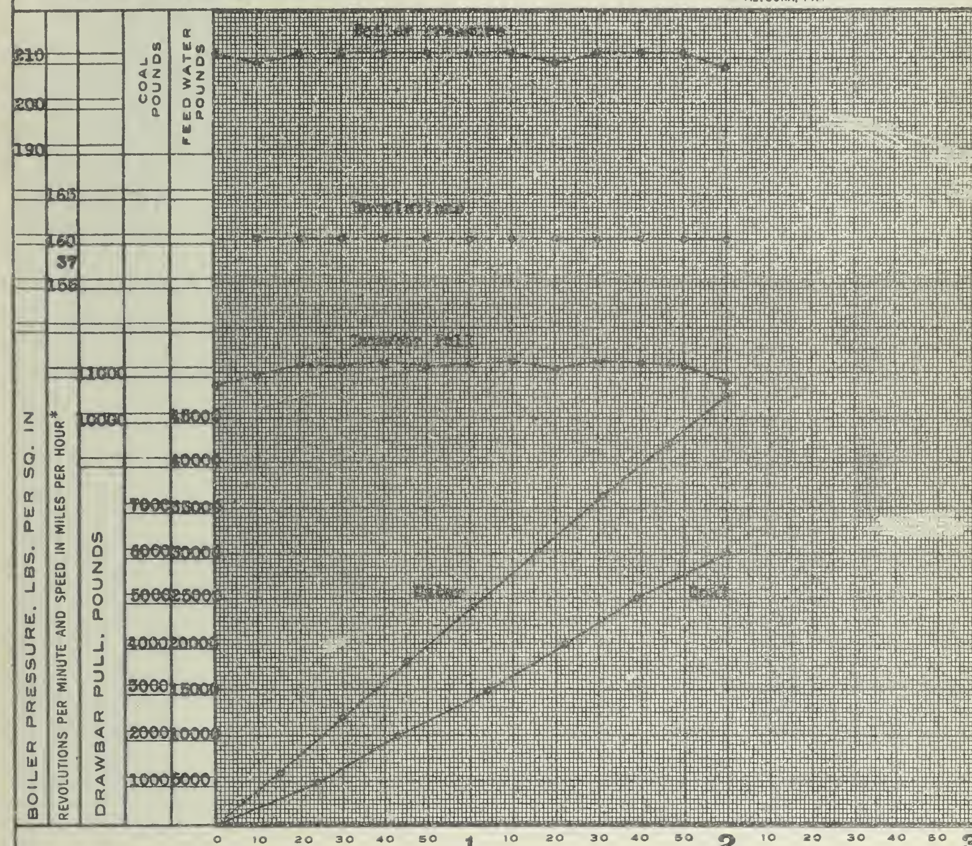
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-1120 TEST DEPARTMENT Bulletin NO. 11

GRAPHICAL LOG OF LOCOMOTIVE TEST

Tests of a Class E3sd Locomotive. ALTOONA, PA. 1-10-1913



LENGTH OF TEST – MINUTES AND HOURS

*UPPER FIGURES R. P. M.
LOWER FIGURES APPROX.
SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 4-4-2
CLASS E3sd
NUMBER 318

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
37.3	160	35	F	7.9

TEST NO. 3113

SHEET NO. P-1120

M. P. Experimental D-1 | 12 9 1912 8 x 10½

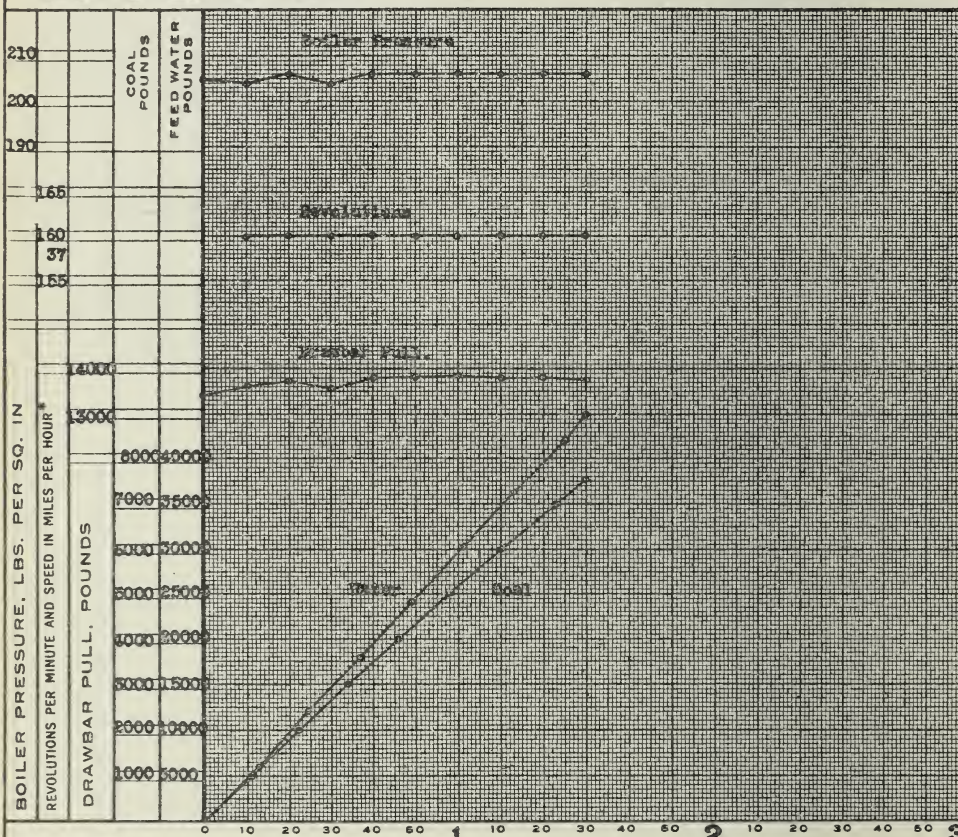
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-1121 TEST DEPARTMENT Bulletin NO. 11

GRAPHICAL LOG OF LOCOMOTIVE TEST

Tests of a Class E3sd Locomotive. ALTOONA, PA. 1-10-1913



*UPPER FIGURES R. P. M.
LOWER FIGURES APPROX.
SPEED IN MILES PER HOUR

LENGTH OF TEST—MINUTES AND HOURS

LOCOMOTIVE
TYPE 4-4-2
CLASS E3sd
NUMBER 318

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
37.3	160	45	F	6.0

TEST NO. 3114

SHEET NO. P-1121

M. P. Experimental D-1

12 9 1912
8 x 10½

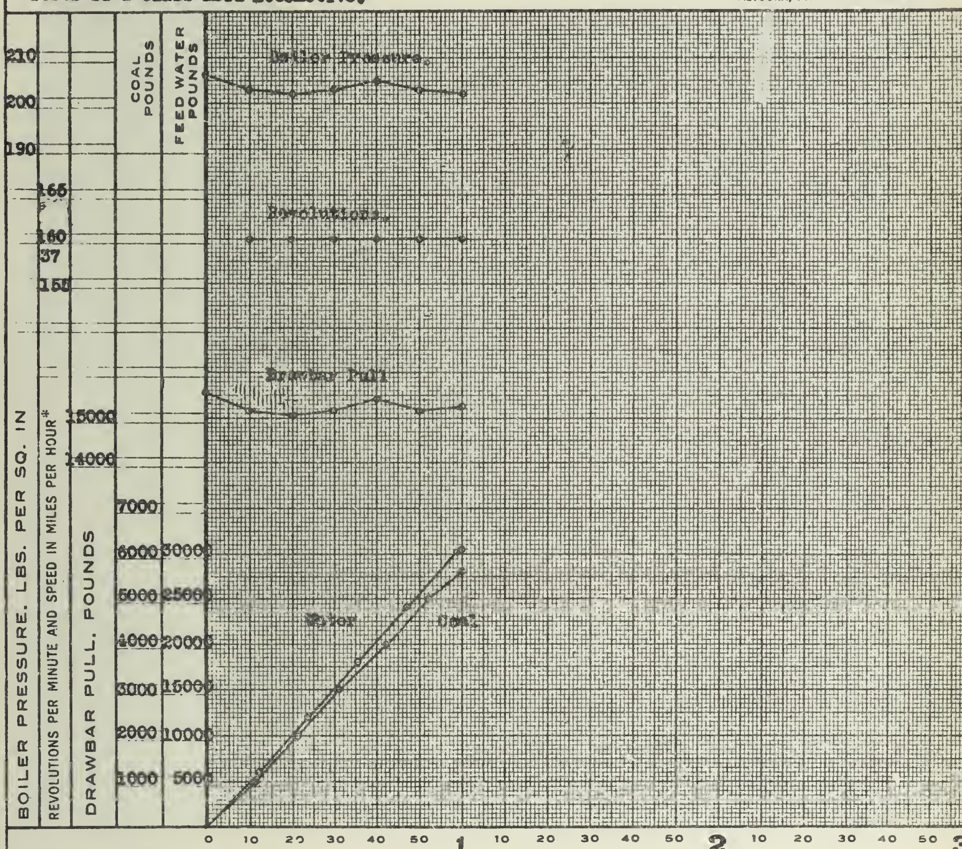
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-1122 TEST DEPARTMENT Bulletin NO. 11

GRAPHICAL LOG OF LOCOMOTIVE TEST

Tests of a Class E3sd Locomotive. ALTOONA, PA 1-23-1913



*UPPER FIGURES R. P. M.
LOWER FIGURES APPROX.
SPEED IN MILES PER HOUR

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
37.3	160	50	F	5.5

TEST NO. 3133

LOCOMOTIVE
TYPE 4-4-2
CLASS E3sd
NUMBER 318

SHEET NO. P-1122

M. P. Experimental D-1

12 9 1912
8 x 10½

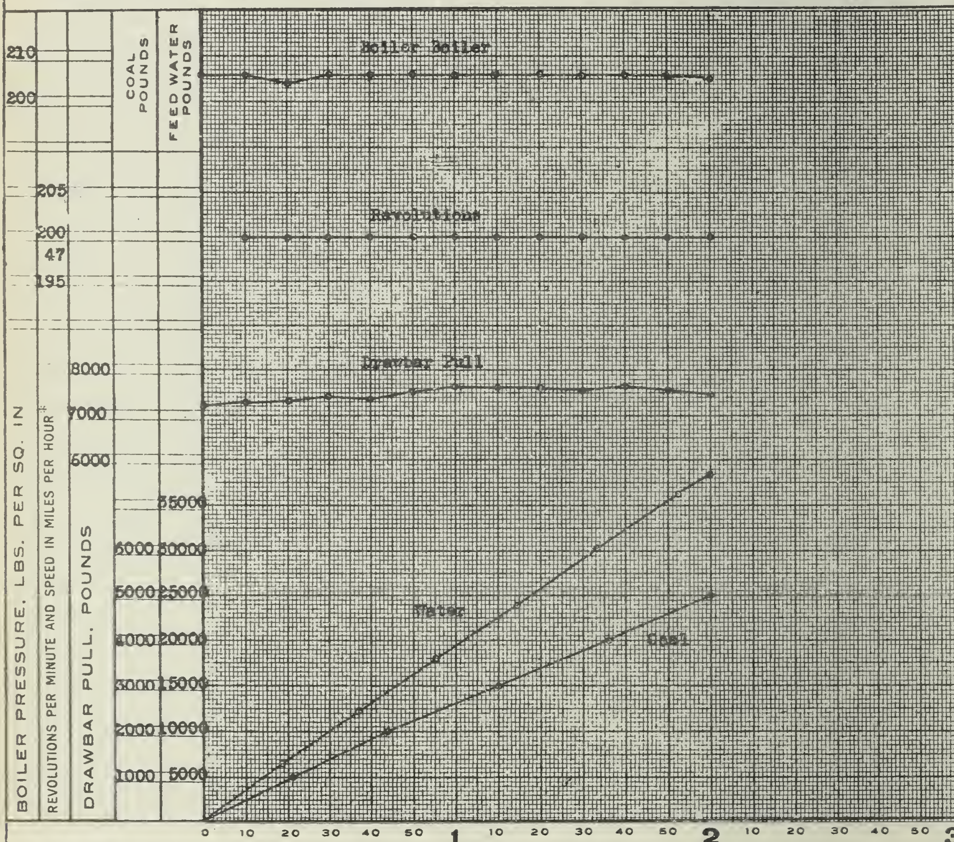
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-1123 TEST DEPARTMENT Bulletin No. 11

GRAPHICAL LOG OF LOCOMOTIVE TEST

Tests of a Class E3sd Locomotive ALTOONA, PA. 1-24-1913



*UPPER FIGURES R. P. M.
LOWER FIGURES APPROX.
SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 4-4-2
CLASS E3sd
NUMBER 318

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
46.7	200	20	F	7.7

TEST NO. 3136

SHEET NO. P-1123

M. P. Experimental D-1

11 9 1912
6 x 10½

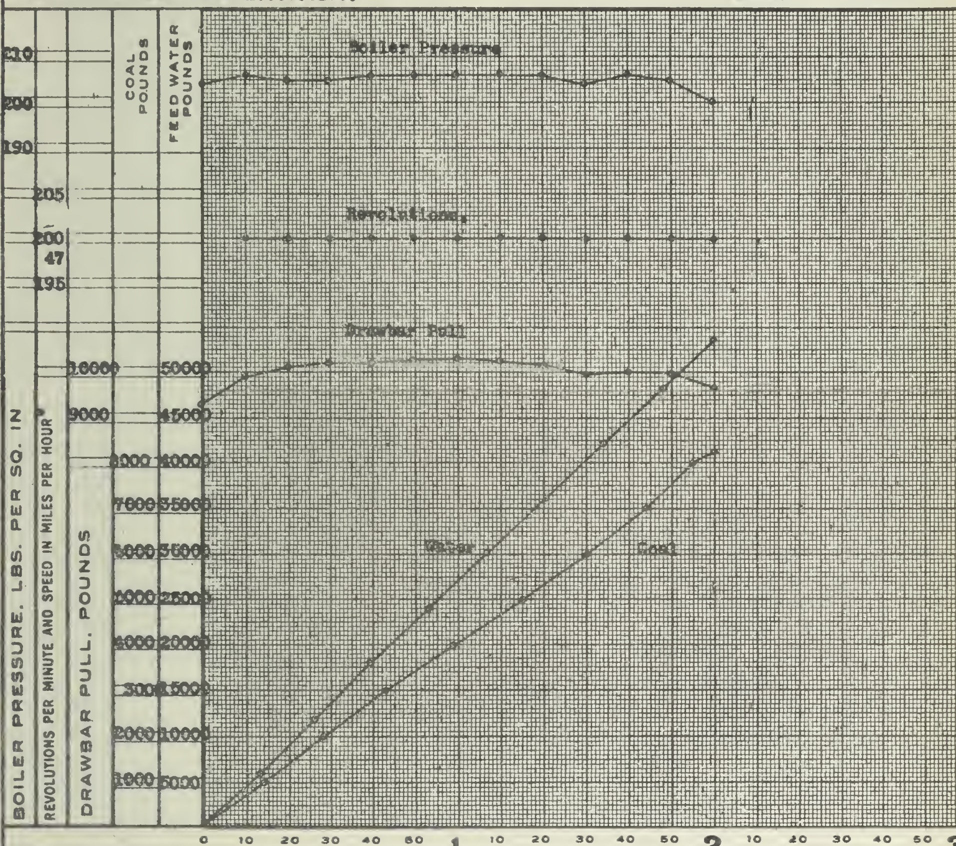
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-1124 TFST DEPARTMENT Bulletin NO. 11

GRAPHICAL LOG OF LOCOMOTIVE TEST

Tests of a Class E3sd Locomotive. ALTOONA, PA. 1-11-1913



*UPPER FIGURES R. P. M.
LOWER FIGURES APPROX.
SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 4-4-2
CLASS E3sd
NUMBER 318

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
46.7	200	35	F	6.5

TEST No. 3115

SHEET NO. P-1124

M. P. Experimental D-1

12 9 1912
8 x 11½

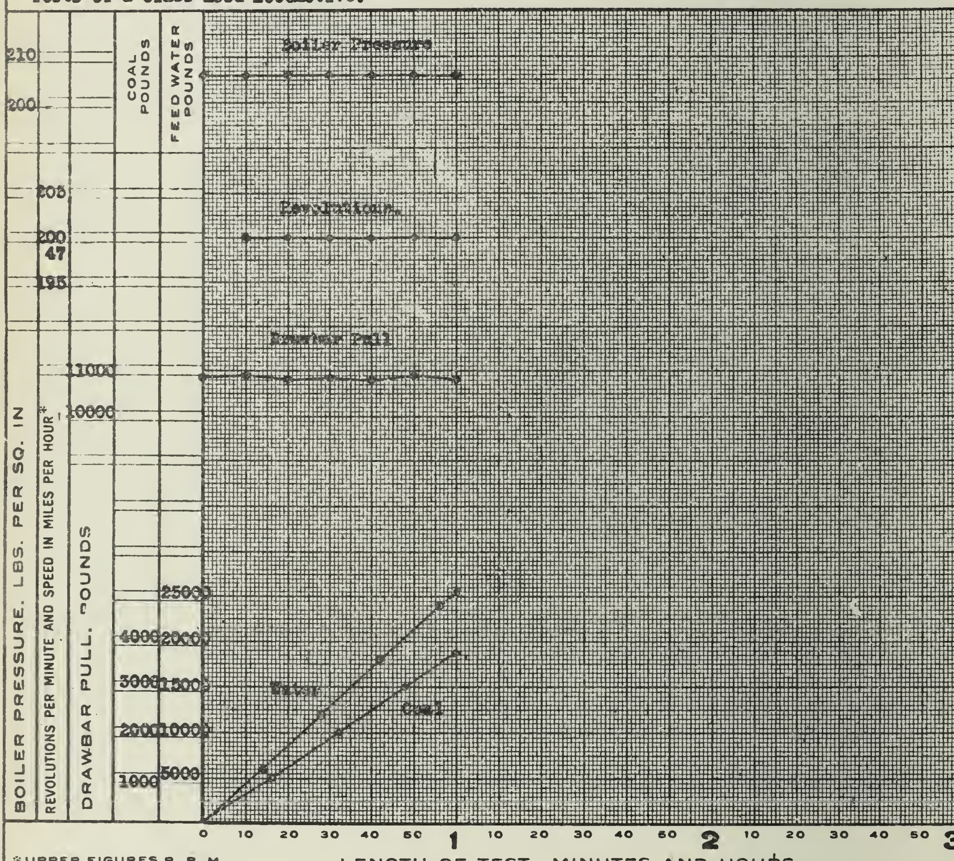
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-1125 TEST DEPARTMENT Bulletin NO. 11

GRAPHICAL LOG OF LOCOMOTIVE TEST

Tests of a Class E3sd Locomotive. ALTOONA, PA., 1-24-1913



*UPPER FIGURES R. P. M.
LOWER FIGURES APPROX.
SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 4-4-2
CLASS E3sd
NUMBER 318

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
46.7	200	35	F	6.9

TEST NO. 3135

SHEET NO. P-1125

M. P. Experimental D-1

12 9 1912
8 x 10½

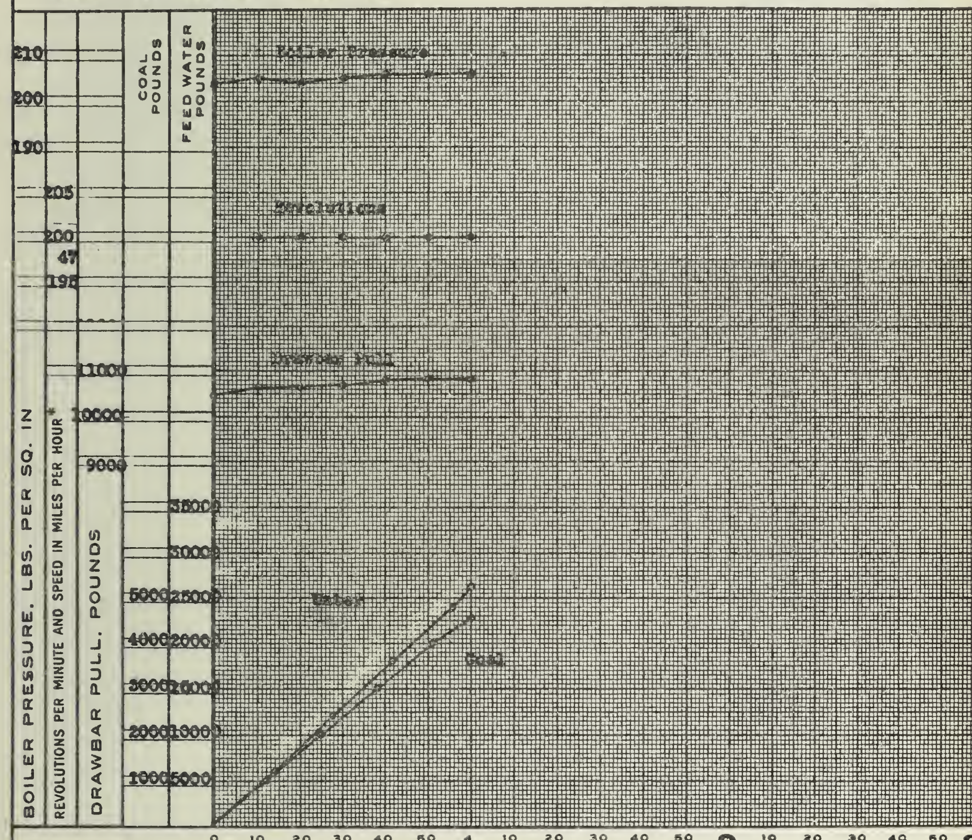
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-1126 TEST DEPARTMENT Bulletin NO. 11

GRAPHICAL LOG OF LOCOMOTIVE TEST

Tests of a Class E3sd Locomotive. ALTOONA, PA. 1-24-1913



LENGTH OF TEST—MINUTES AND HOURS

*UPPER FIGURES R. P. M.
LOWER FIGURES APPROX.
SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 4-4-2
CLASS E3sd
NUMBER 518

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
46.7	200	35	F	5.7

TEST NO. 3134

SHEET NO. P-1126

M. P. Experimental D-1

13 9 1912 / 8 x 10½

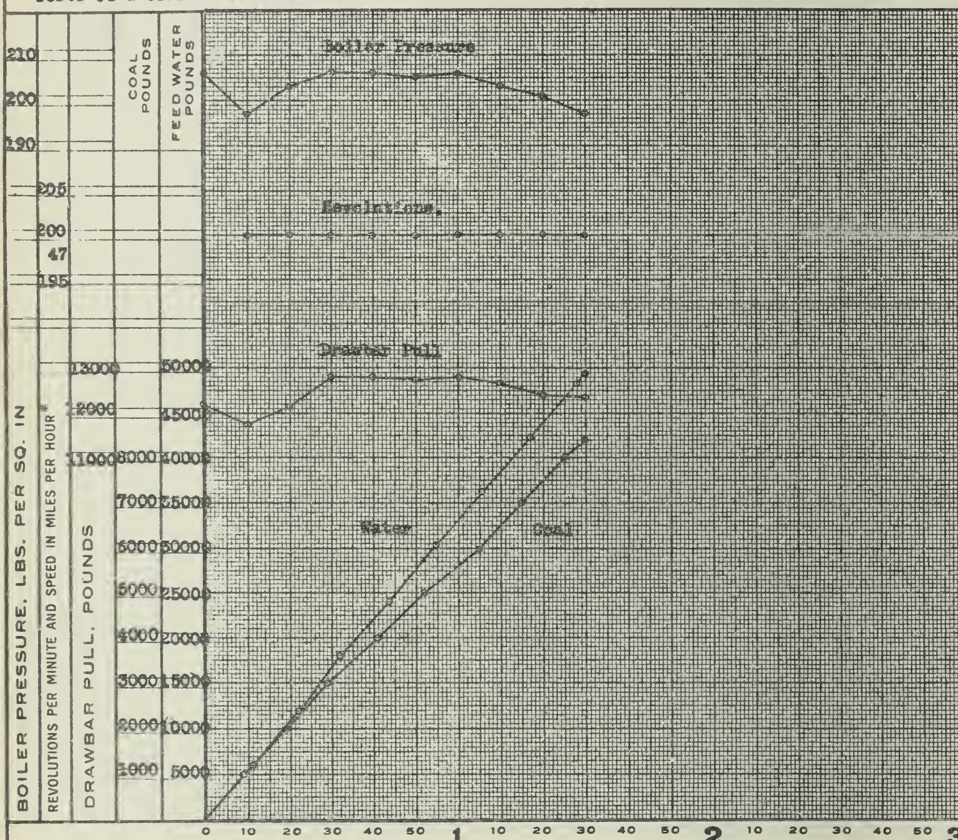
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-1127 TEST DEPARTMENT Bulletin NO. 11

GRAPHICAL LOG OF LOCOMOTIVE TEST

Tests of a Class E3sd Locomotive. ALTOONA, PA.. 1-18-1913



*UPPER FIGURES R. P. M.
LOWER FIGURES APPROX.
SPEED IN MILES PER HOUR

LENGTH OF TEST—MINUTES AND HOURS

LOCOMOTIVE
TYPE 4-4-2
CLASS E3sd
NUMBER 318

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
46.7	200	45	F	5.9

TEST NO. 3124

SHEET NO. P-1127

M. P. Experimental D-1

12 9 1912
8 x 10½

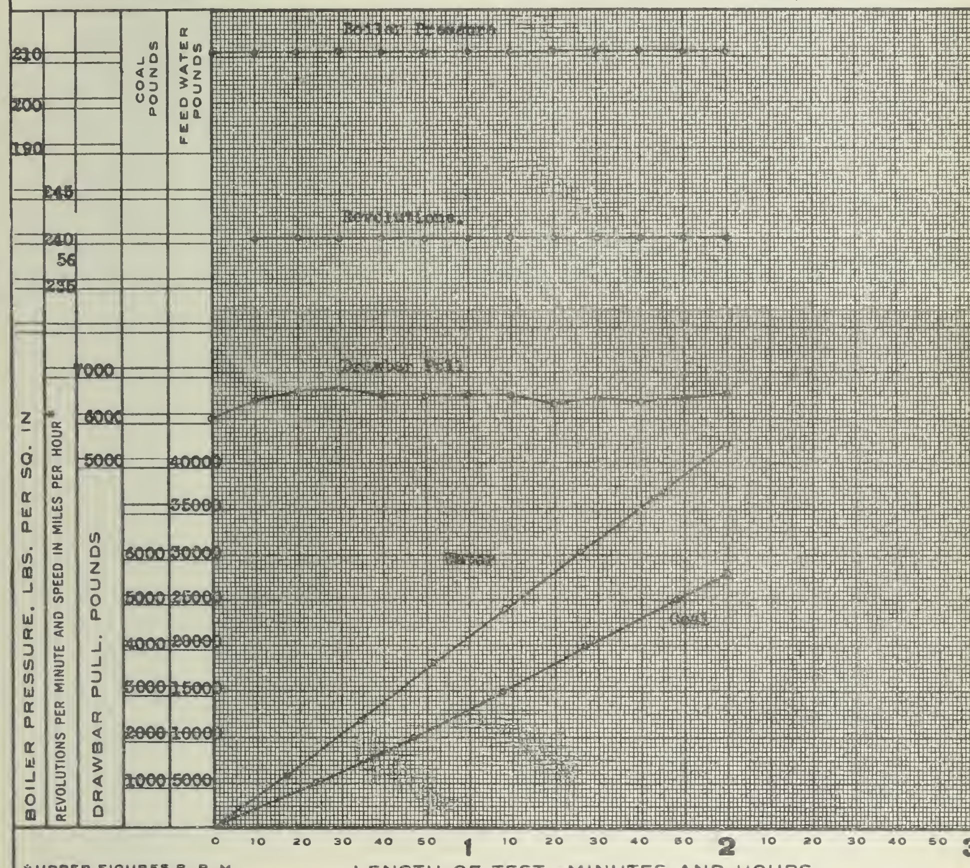
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO P-1128 TEST DEPARTMENT Bulletin NO. 11

GRAPHICAL LOG OF LOCOMOTIVE TEST

Tests of a Class E3sd Locomotive. ALTOONA, PA. 1-13-1913



*UPPER FIGURES R. P. M.
LOWER FIGURES APPROX.
SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 4-4-2
CLASS E3sd
NUMBER 318

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
56.0	240	20	F	7.6

TEST NO. 5117

SHEET NO. P-1128

M. P. Experimental D-1

12 9 1912
8 x 10½

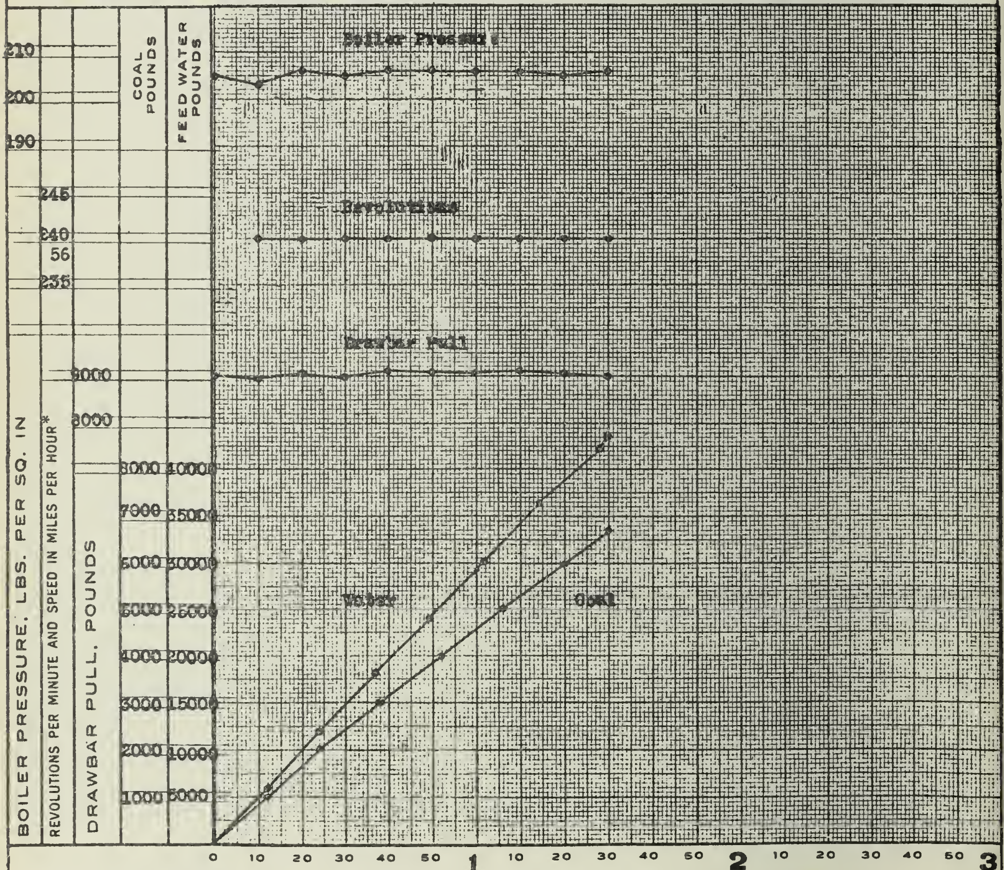
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-1129 TEST DEPARTMENT BulletinNo. 11

GRAPHICAL LOG OF LOCOMOTIVE TEST

Tests of a Class E3sd Locomotive. ALTOONA, PA. 4-13-1913



*UPPER FIGURES R. P. M.
LOWER FIGURES APPROX. SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 4-4-2
CLASS E3sd
NUMBER 318

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
56.0	240	35	F	6.5

TEST No. 3116

SHEET No. P-1129

M. P. Experimental D-1

12 9 1912
8 x 10½

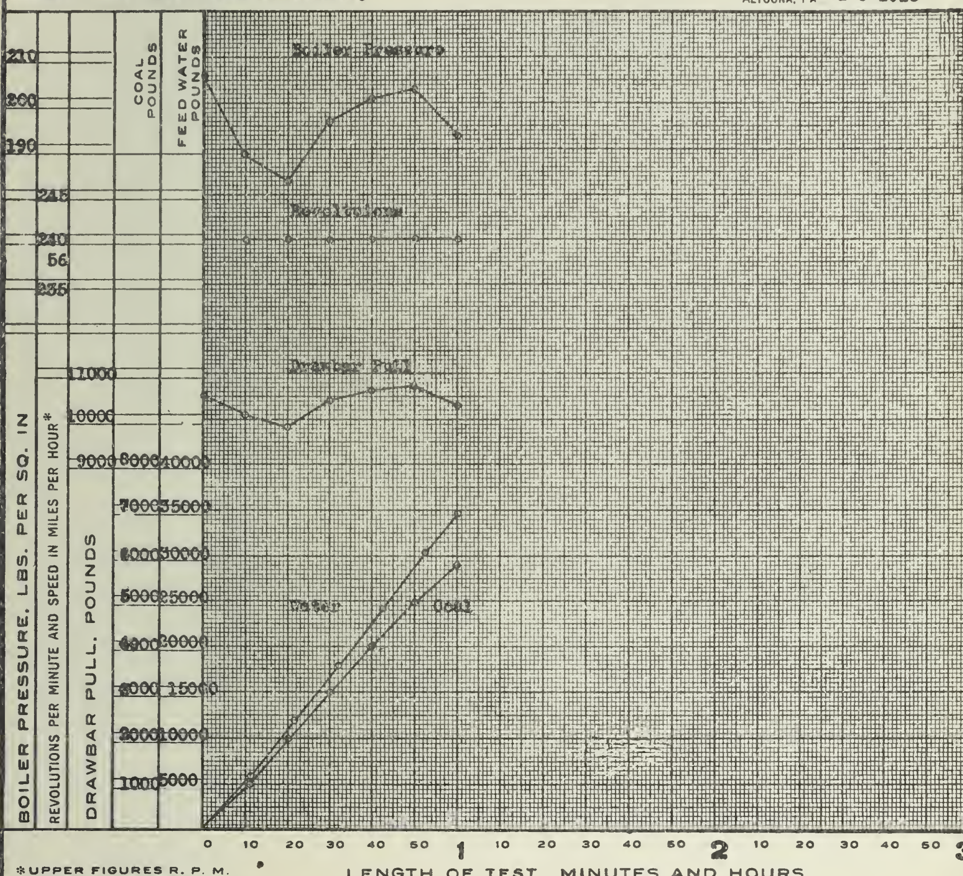
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-1130 TEST DEPARTMENT Bulletin NO 11

GRAPHICAL LOG OF LOCOMOTIVE TEST

Tests of a Class E3sd Locomotive. ALTOONA, PA 1-8-1913



*UPPER FIGURES R. P. M.
LOWER FIGURES APPROX.
SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 4-4-2
CLASS E3sd
NUMBER 318

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
56.0	240	45	F	6.0

TEST NO. 3109

SHEET NO. P-1130

M. P. Experimental D-1

12 9 1912
8 x 10½

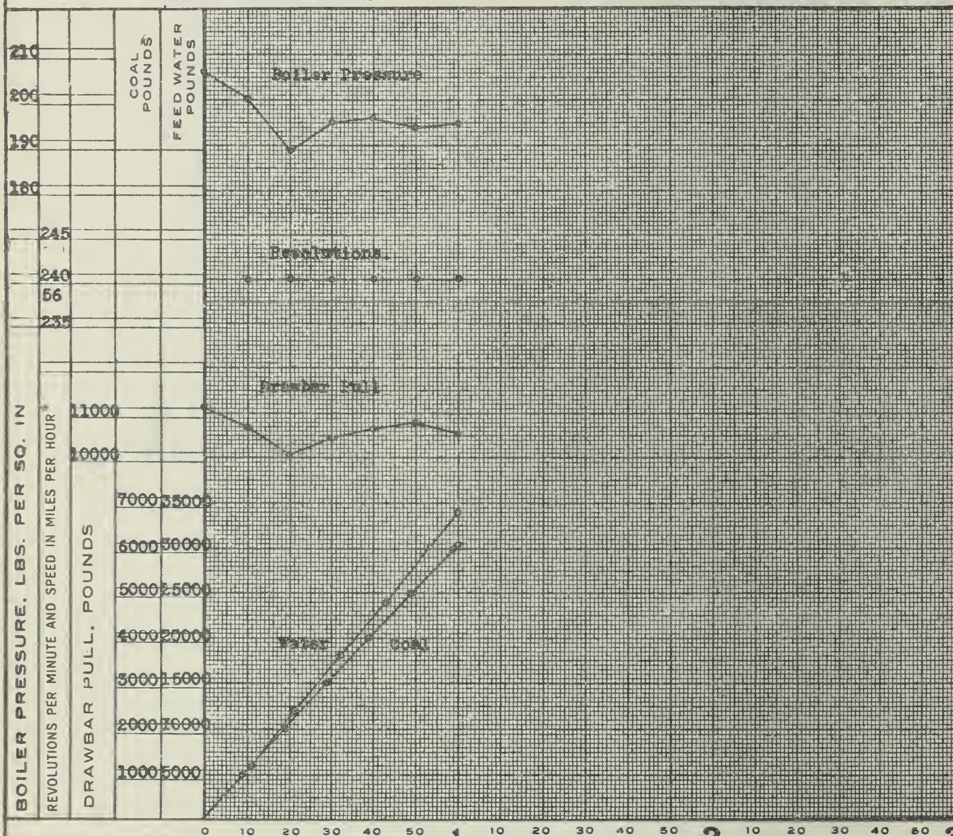
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-1131 TEST DEPARTMENT Bulletin NO. 11

GRAPHICAL LOG OF LOCOMOTIVE TEST

Tests of a Class E3sd Locomotive. ALTOONA, PA. 1-27-1913



*UPPER FIGURES R. P. M.
LOWER FIGURES APPROX.
SPEED IN MILES PER HOUR

LENGTH OF TEST—MINUTES AND HOURS

LOCOMOTIVE
TYPE 4-4-2
CLASS E3sd
NUMBER 318

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
56.0	240	45	F	5.6

TEST NO. 3139

SHEET NO. P-1131

M. P. Experimental D-1

12 9 1912
8 x 10½

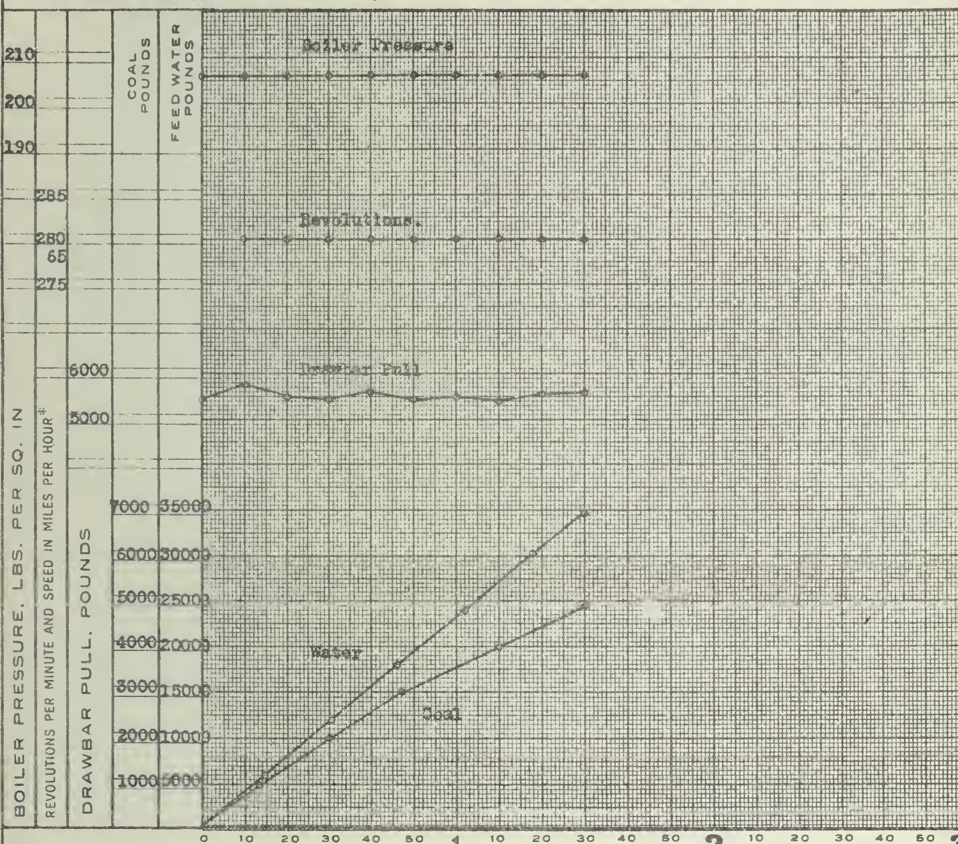
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-1132 TEST DEPARTMENT Bulletin NO. 11

GRAPHICAL LOG OF LOCOMOTIVE TEST

Tests of a Class E3sd Locomotive. ALTOONA, PA 1-14-13



LENGTH OF TEST—MINUTES AND HOURS

*UPPER FIGURES R. P. M.
LOWER FIGURES APPROX.
SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 4-4-2
CLASS E3sd
NUMBER 318

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
65.4	280	20	F	7.1

TEST NO. 3119

SHEET NO. P-1132

M. P. Experimental D-1

12 9 1912
8 x 10½

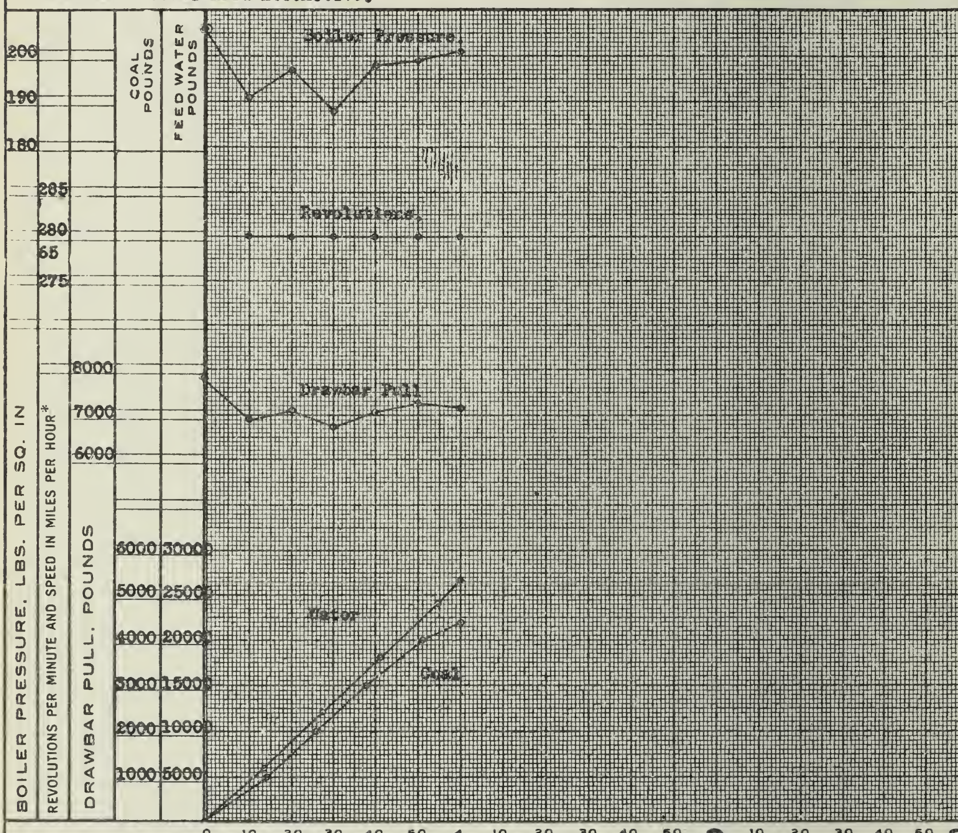
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-1133 TEST DEPARTMENT Bulletin NO. 11

GRAPHICAL LOG OF LOCOMOTIVE TEST

Tests of a Class E3sd Locomotive. ALTOONA, PA. 1-16-1913



*UPPER FIGURES R. P. M.
LOWER FIGURES APPROX.
SPEED IN MILES PER HOUR

LENGTH OF TEST MINUTES AND HOURS

LOCOMOTIVE
TYPE 4-4-2
CLASS E3sd
NUMBER 318

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
65.4	280	30	F	6.1

TEST NO. 3122

SHEET NO. P-1133

M. P. Experimental D-1

12 9 1912
6 x 10½

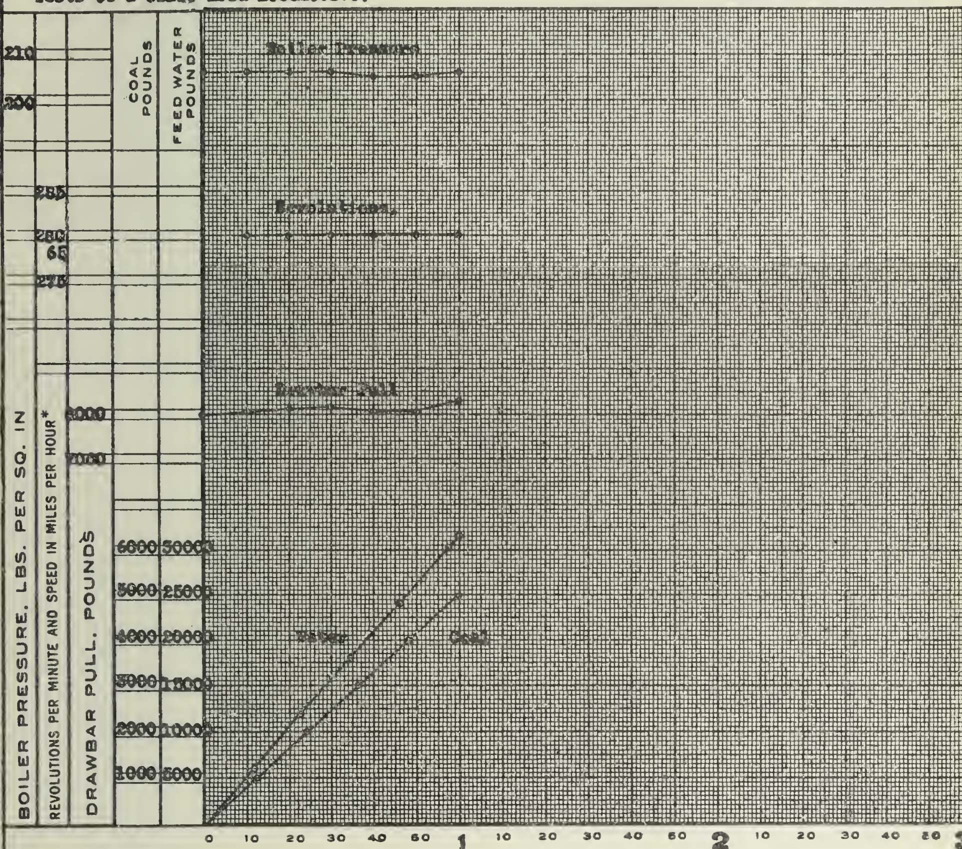
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-1134 TEST DEPARTMENT Bulletin NO. 11

GRAPHICAL LOG OF LOCOMOTIVE TEST

Tests of a Class E3sd Locomotive. ALTOONA, PA. 1-20-1913



*UPPER FIGURES R. P. M.
LOWER FIGURES APPROX.
SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 4-4-2
CLASS E3sd
NUMBER 318

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
65.4	280	35	F	6.3

TEST NO. 3125

SHEET NO. P-1134

M. P. Experimental D-1

12-9-1912
8 x 10½

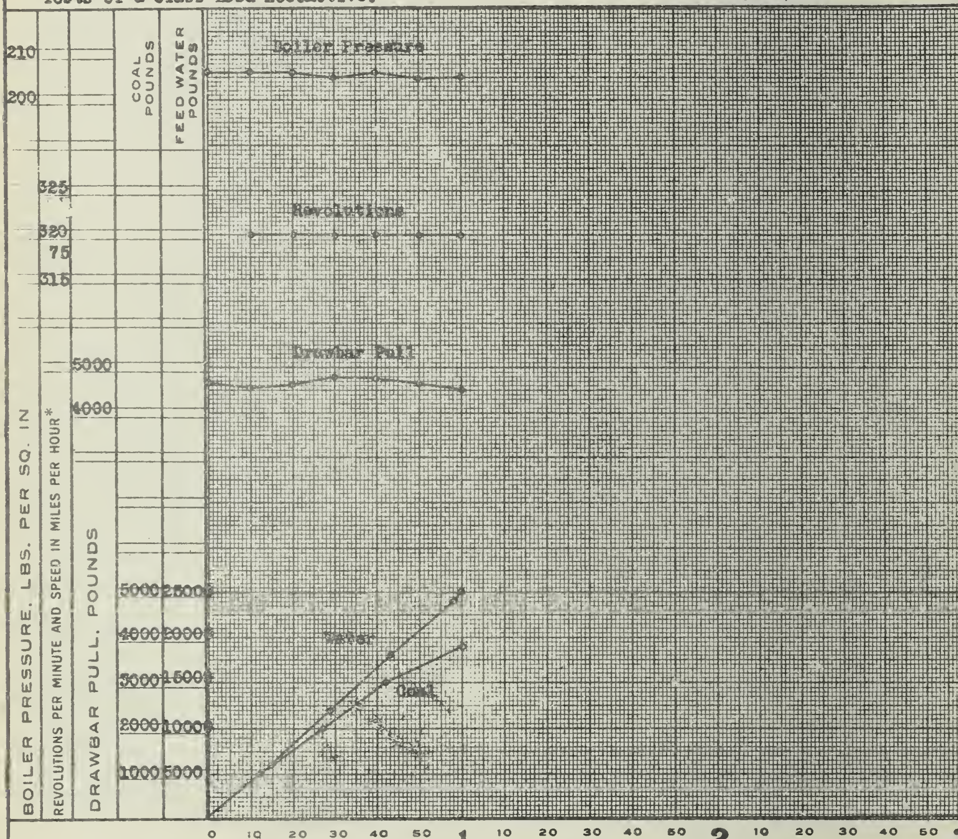
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO P-1135 TEST DEPARTMENT Bulletin NO. 11

GRAPHICAL LOG OF LOCOMOTIVE TEST

Tests of a Class E3sd Locomotive. ALTOONA, PA. 1-20-1913



LENGTH OF TEST – MINUTES AND HOURS

*UPPER FIGURES R. P. M.
LOWER FIGURES APPROX. SPEED IN MILES PER HOUR

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
74.7	320	20	F	6.5

LOCOMOTIVE
TYPE 4-4-2
CLASS E3sd
NUMBER 318

TEST NO. 3126

SHEET NO. P-1135

M. P. Experimental D-1

PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY

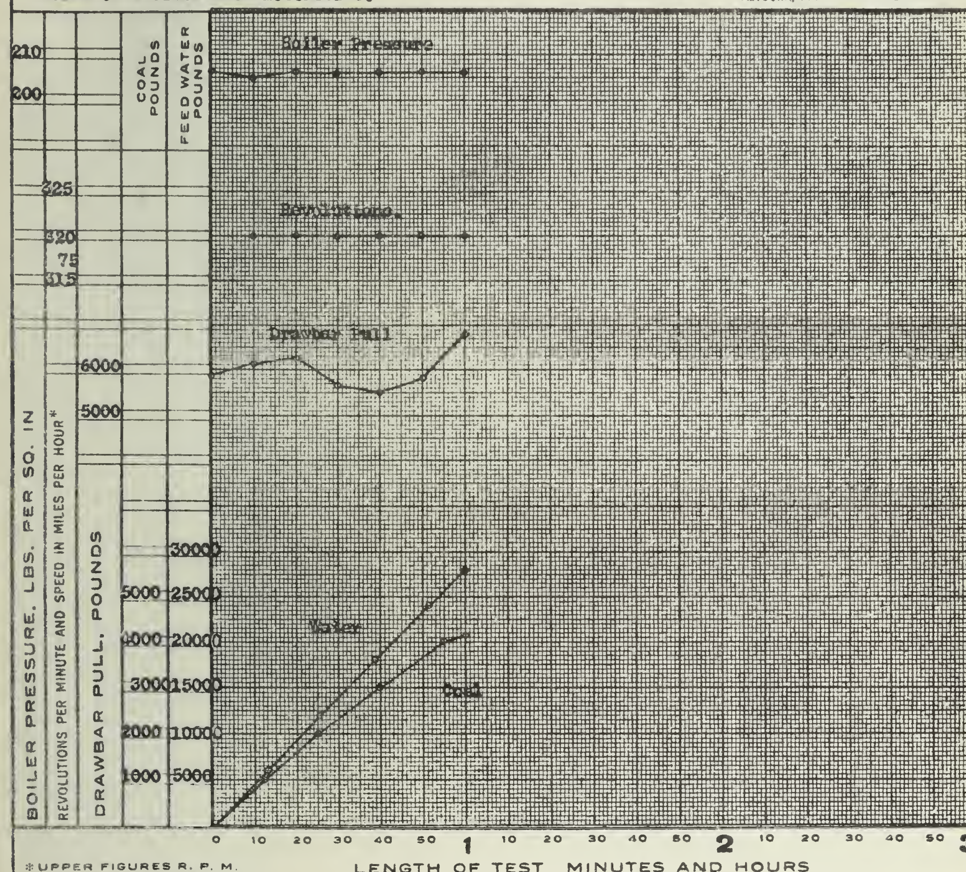
NORTHERN CENTRAL RAILWAY COMPANY

WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-1136 TEST DEPARTMENT Bulletin NO 11

GRAPHICAL LOG OF LOCOMOTIVE TEST

Tests of a Class E3sd Locomotive. ALTOONA, PA. 1-21-1913



*UPPER FIGURES R. P. M.
LOWER FIGURES APPROX.
SPEED IN MILES PER HOUR

LOCOMOTIVE

TYPE 4-4-2

CLASS E3sd

NUMBER 318

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
74.7	320	25	F	6.7

TEST NO. 3128

SHEET NO. P-1136

M. P. Experimental D-1

12 9 1912
8 x 10½

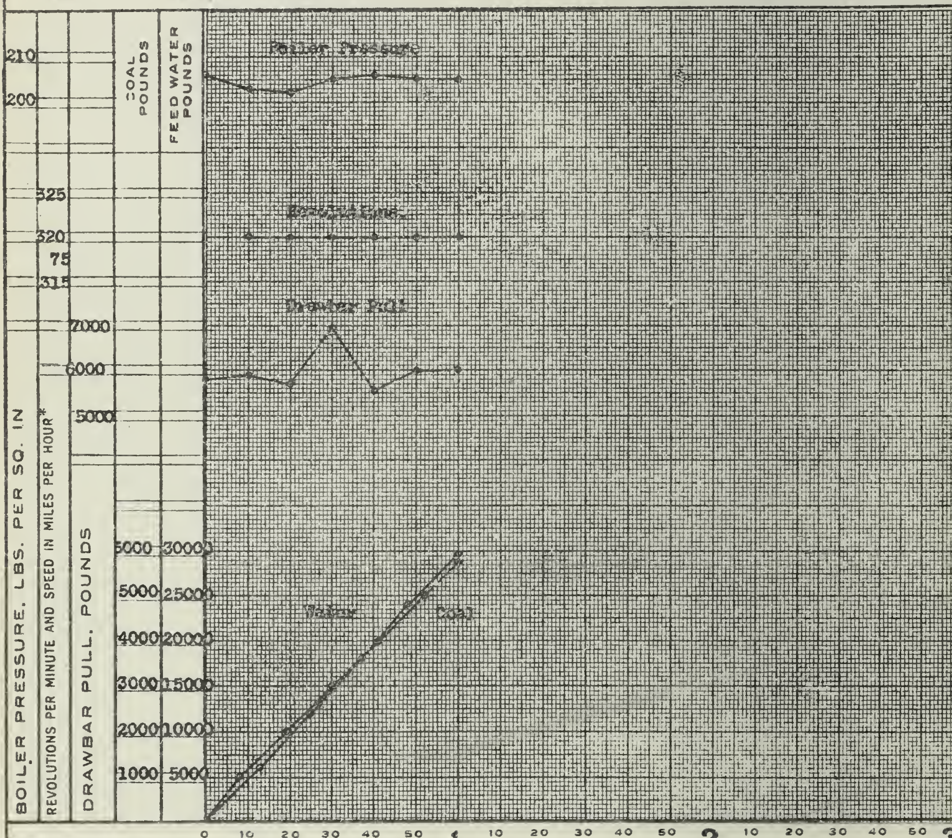
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-1137 — TEST DEPARTMENT — Bulletin NO. 11

GRAPHICAL LOG OF LOCOMOTIVE TEST

Tests of a Class E3sd Locomotive. — ALTOONA, PA. 1-21-1913



LENGTH OF TEST—MINUTES AND HOURS

*UPPER FIGURES R. P. M.
LOWER FIGURES APPROX.
SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 4-4-2
CLASS E3sd
NUMBER 318

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
74.7	320	30	F	5.2

TEST NO. 3127

SHEET NO. P-1137

M. P. Experimental D-1

12 9 1912
8 x 10½

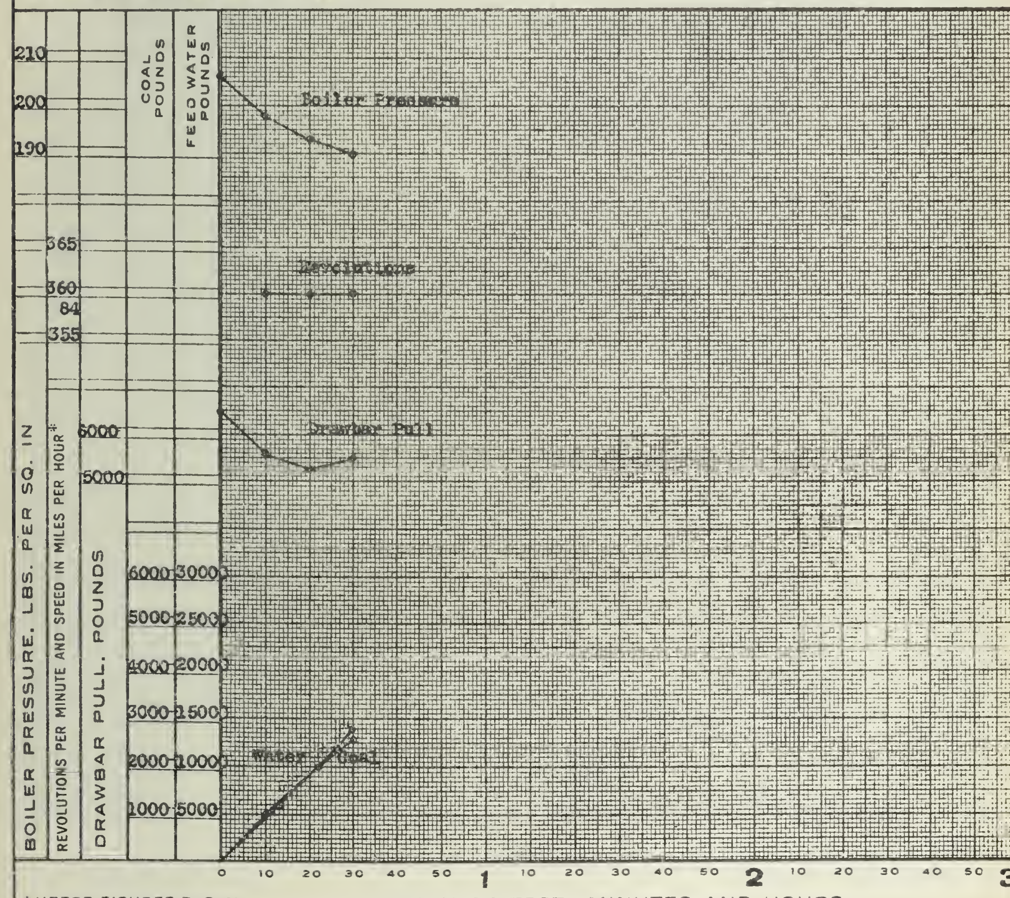
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-1138 TEST DEPARTMENT Bulletin NO. 11

GRAPHICAL LOG OF LOCOMOTIVE TEST

Tests of a Class E3sd Locomotive. ALTOONA, PA. 1-27-1913



* UPPER FIGURES R. P. M.
LOWER FIGURES APPROX.
SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 4-4-2
CLASS E3sd
NUMBER 318

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
83.9	360	25	F	5.3

TEST NO. 3142

SHEET NO. P-1138

M. P. Experimental D-1

12 9 1912
8 x 10½

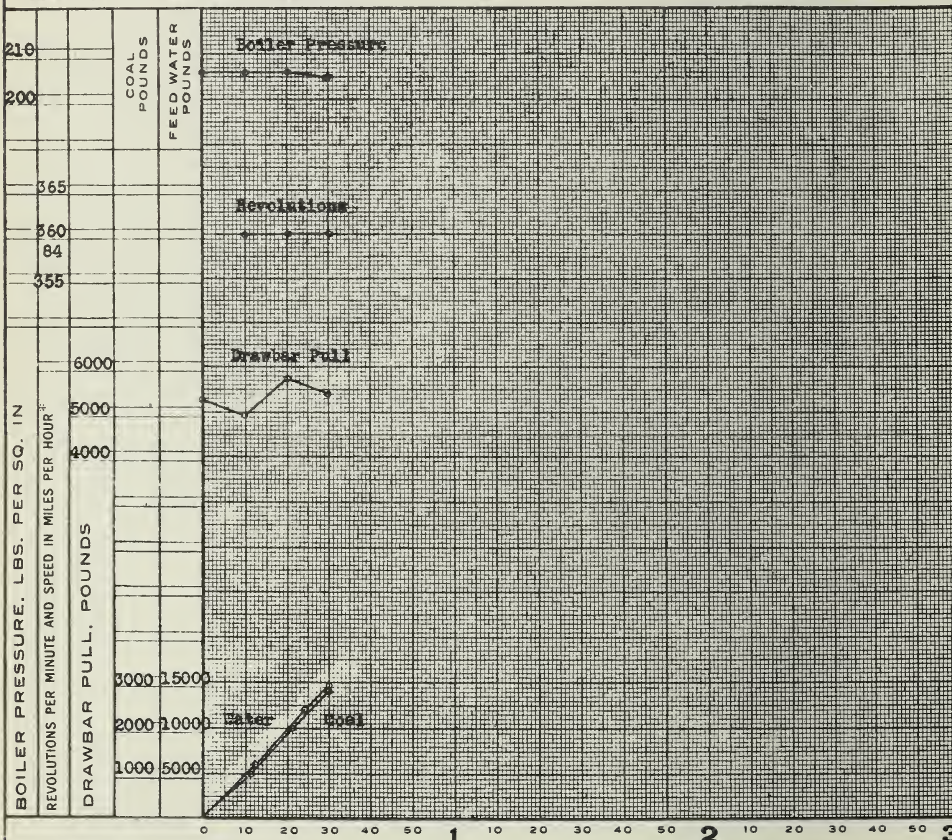
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-1139 TEST DEPARTMENT Bulletin NO. 11

GRAPHICAL LOG OF LOCOMOTIVE TEST

Tests of a Class E3sd Locomotive. ALTOONA, PA 1-28-1913



*UPPER FIGURES R. P. M.
LOWER FIGURES APPROX.
SPEED IN MILES PER HOUR

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
83.9	360	25	F	5.3

LOCOMOTIVE
TYPE 4-4-2
CLASS E3sd
NUMBER 318

TEST NO. 3143

SHEET NO. P-1139

INDEX.

The numbers refer to pages.

PENNSYLVANIA RAILROAD COMPANY

Locomotive Testing Plant

AT

ALTOONA, PENNA.

BULLETIN No. 12 (Revised)

Formerly Bulletin No. 15

BANK VERSUS LEVEL FIRING

1912

THE H6b CLASS LOCOMOTIVE.
The type of locomotive used in the Bank and Level Fire tests.

LOCOMOTIVE TESTING PLANT.

BANK VERSUS LEVEL FIRING

Two methods of Locomotive Firing and the results from a competitive trial under Test Plant conditions.

Conclusions and Recommendations on pages 19 and 20.

INTRODUCTION.

1. This series of trials of level and of bank fires in a locomotive has resulted in a general conclusion that the best practice in firing is to keep the fire level and bright, and at the same time as thin as is possible, in order to carry the load upon the boiler.

2. There are, on the Pennsylvania Lines both East and West, nearly two thousand consolidation locomotives of the H6b class. They have a wide firebox and a nearly level grate. The bituminous coal burned in them is from over one hundred mines, for the most part in Pennsylvania, but extending all the way to the Illinois fields. It is to be expected, with this diversity of coals and the large number of men who fire these locomotives, that differences in method of firing will occur. Firemen are instructed, by the road foreman, to fire by the level fire method, and this method is in general use. It consists in maintaining a fire of uniform thickness over the whole grate, feeding coal to all parts in small quantities so as to have a bright fire over the whole surface and one that is just thick enough to carry the load upon the boiler.

3. Another method is that known as bank firing, and consists in building up, at the back end of the fire, a bank or ridge of fuel, just inside of the firedoor. This ridge of fuel when built up to its full height, has its top at about the level of the top of the firedoor. Coal is fired over the top of this bank and slides down the incline toward the front of the firebox, being assisted by the slope of the grate. It is distributed along the apex of the ridge or bank

and allowed to find its way down to the level portion of the fire at the front end of the grate. The fuel bed under these conditions is not all burning at the same rate but the thick portion or bank is cooler, the more intense fire being at the forward end of the firebox where the fuel bed is thin.

4. The claims of superiority for this method over level firing are: The fuel being heaped up at the rear of the firebox, is coked, the hydrocarbons are driven off slowly and traversing the whole length of the firebox, are burned with little smoke; the bank of green coal, extending up over the door opening, protects the fireman from part of the heat that is radiated from the fire; the work of placing the fuel is simplified, the coal being fed to the top of the bank at a point near the firedoor instead of being distributed over the whole grate surface. These advantages, if real, ought to be capable of demonstration by trial, and in order to make a comparison of bank firing with level firing a series of tests have been made at the Locomotive Testing Plant.

Firemen.

5. The firemen for the tests were selected from men skilled in the use of these two methods of firing. Two of them were strong advocates of the bank fire and had been firing according to this method in their regular road work on the Lines West. Two men were from the divisions where bank firing was practiced on the Lines West, but they believed in and practiced level firing. In addition, there were two Test Plant firemen who were from the Lines East and had become expert in firing by the level fire method. A level fire fireman from the Lines East also assisted in the trial. These firemen will be designated as follows:

B1,	Advocate	of	bank	firing,	Lines	West.
B2,	“	“	“	“	“	“
L1,	“	“	level	“	“	“
L2,	“	“	“		“	“
L3,	“	“	“	“	“	“

T1, Test Plant fireman level fire.
T2, “ “ “ “ “

R, Road fireman level fire Lines East.

The Locomotive.

6. The tests were made with an H6b class locomotive 2860. A drawing of this locomotive is shown in Fig. 1. Table 3 gives the principal dimensions. There was no arch in the firebox. The grate is long and wide (8 feet $10\frac{1}{2}$ inches long and 5 feet 6 inches wide) and nearly level.

7. There are drop grates at the front and rear, with 18 sections of shaking grate bars between. The grate area is 48.66 square feet. The air openings through the grate have a total area of 17.6 square feet or 36.4 per cent. of the grate.

The Coal.

8. The coal used was of two kinds. In the first three tests, Nos. 1275 to 1277, coal from the Pennsylvania and Northwestern region in Pennsylvania was used. This is a high carbon bituminous coal, with little ash, and will be designated as Eureka No. 6. It is fairly representative of the coal used on the Lines East, in the H6b locomotive.

9. For the remaining tests, coal from the Pittsburgh Coal Company was used. This is known as No. 8 Pittsburgh Steam Coal. It is a high volatile coal with a rather high amount of ash. This coal is used on the Lines West.

An analysis of each coal shows the following:

	Eureka "No. 6"	*Pittsburgh Coal Co.*
Fixed carbon, per cent.	60.10	48.17
Volatile combustible, per cent.	30.36	36.37
Moisture, per cent.	0.74	2.04
Ash, per cent.	8.80	13.42
	100.00%	100.00%
Sulphur determined separately,	2.08	3.18
Calorific value, B. t. u. per pound dry,	13743	12364

The Level Fire.

10. The methods used in firing the level fire were much the same in the case of each of the level fire firemen. The coal was broken rather fine, to two inches in thickness or less, and was fired in single shovelfuls or at a uniform rate. Fig. 2 shows the probable appearance of a section of the level fire on the grate.

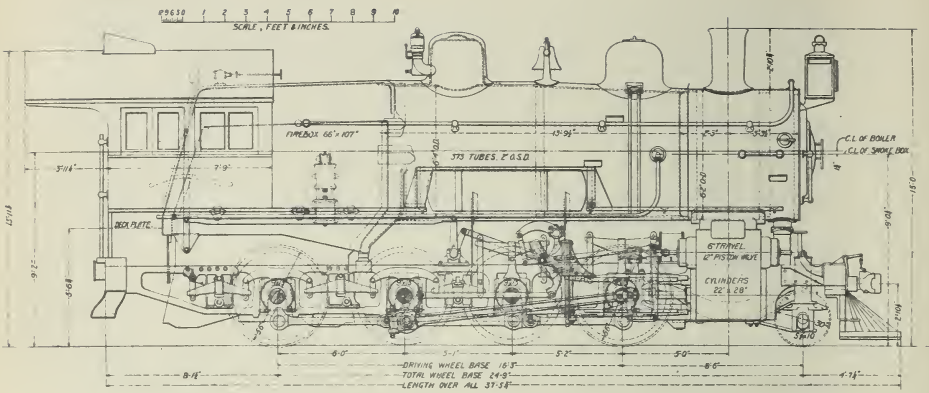


Fig 1.
CLASS H6b LOCOMOTIVE.
The Locomotive used in the Tests.

THE LEADING DIMENSIONS OF THE "H6b" LOCOMOTIVE ARE AS FOLLOWS:

Total weight, pounds	198,267
Weight on drivers, pounds	176,600
Cylinders (simple), inches	22x28
Diameter of drivers, inches	56
Firebox heating surface, square feet	166.4
Heating surface in tubes (water side), square feet	2673.68
Total heating surface (based on water side of tubes), square feet	2839.74
Total heating surface (based on fire side of tubes), square feet	2505.29
Grate area, square feet	48.66
Boiler pressure, pounds	205
Valves	American, Stayman and "L" type
Valve motion	Walschaerts
Firebox, type	Belpaire
Number of tubes	373
Outside diameter of tubes, inches	2
Length of tubes, inches	164.28

The maximum tractive effort is 39,773 pounds, which is calculated on the assumption that 80 per cent. of the boiler pressure (205 pounds) is available as mean effective pressure at starting.

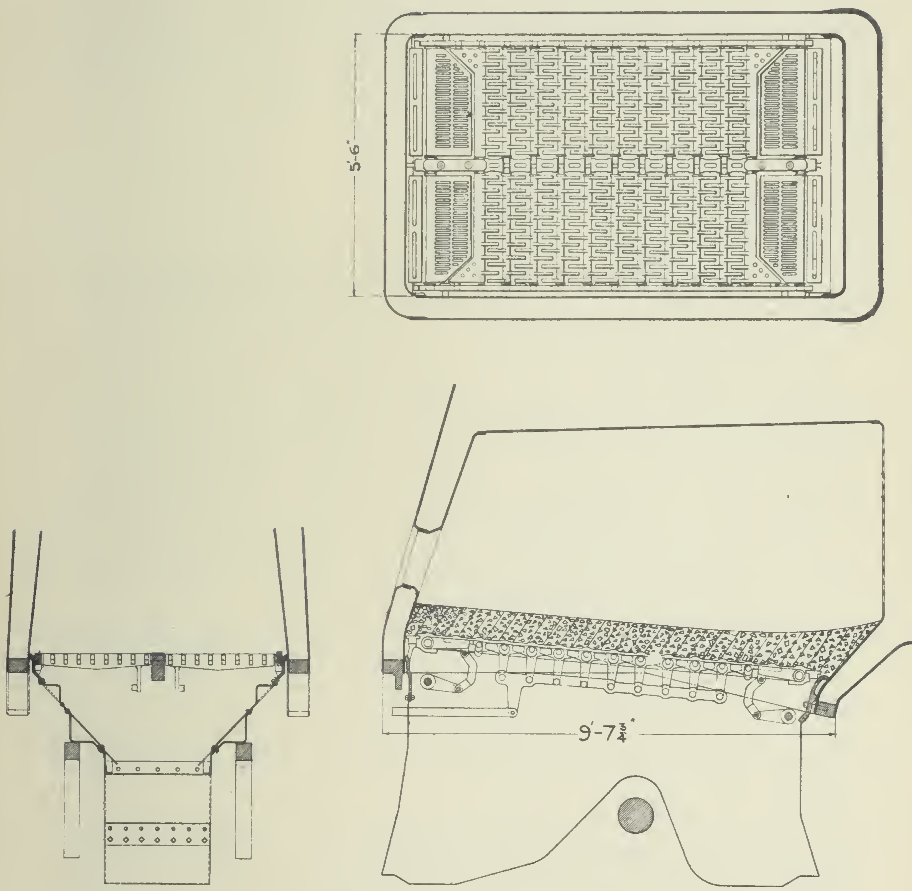


Fig. 2.
LEVEL FIRE.
A plan of the grate and a longitudinal section are shown.

The Bank Fire.

11. The bank-fire fireman did not follow strictly the method of firing the bank fire as given above. A low bank, as shown in Fig. 3, was built up, but with the exception of test No. 1278, the bank served only as a partial protection from the heat and glare of the fire, the coal being fired in small quantities and uniformly over the entire grate, except over the bank. The bank top was about 18 inches inside of the firedoor, and with the bank so low that on this practically level grate it is evident the coal would not slide by gravity to the front of the firebox. In test No. 1278 an attempt was made to fire by placing all of the coal on the top of the bank. The top of the bank in this case was about $3\frac{1}{2}$ feet inside of the firedoor and the fire at the front of the firebox was very thin.

The Tests.

12. The tests were made at speeds of 80 revolutions per minute, about 13 miles per hour, and at 100 revolutions, about 17 miles per hour, with wide open throttle and were two and one-half hours long, except in two cases.

13. In bank-fire tests Nos. 1277 and 1278 the same man fired throughout, but in the other bank-fire tests the fire was prepared by the Test Plant fireman and, at the instant of starting the test, turned over to the bank fireman to build up the bank and continue firing to the end of the test. Just before the end of these later bank-fire tests the bank was allowed to burn down. This was done in order, and in a way to make sure that the condition of the fire would be the same at the end of the test as at the start, so that the coal supply could be accurately weighed. The bank would be burned out in less than seven minutes. All of the firing, both level and bank, was continuous, small quantities being fired at one time and the coal was broken down before firing.

14. In Tables 1 and 2 a summary of the results of the tests is given. The tests in Table 1 were run at a speed equivalent to about 13 miles per hour and a cut-off of 40 per cent., giving an evaporation of about 11 pounds of water per square foot of

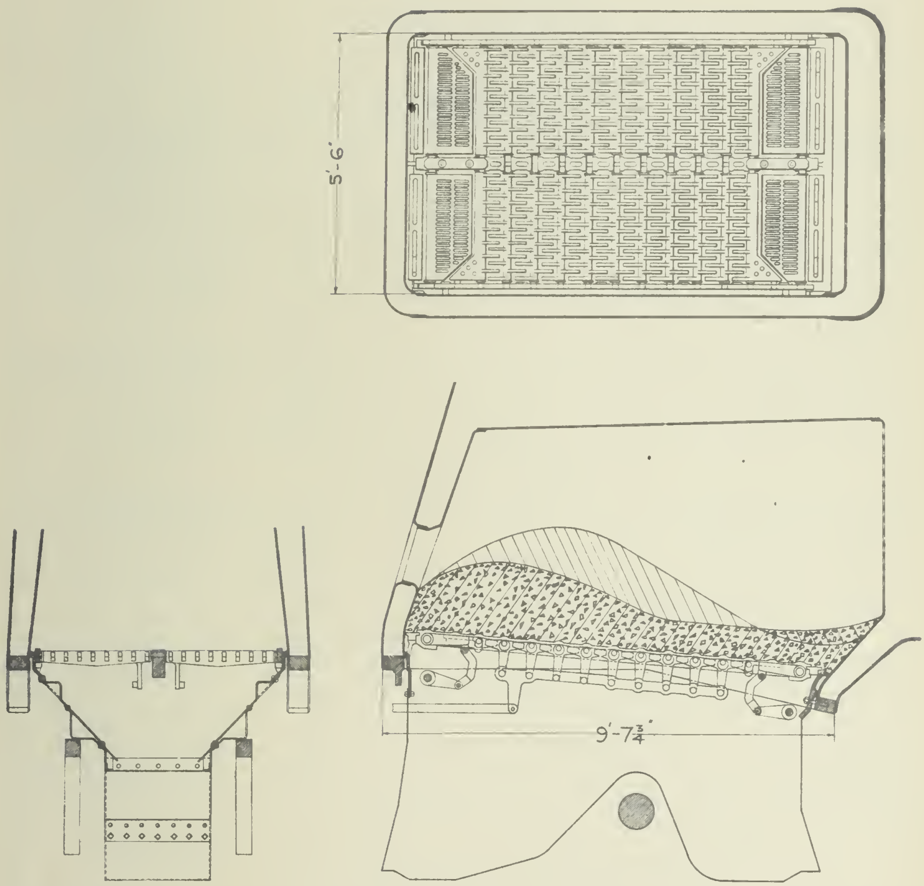


Fig. 3.

BANK FIRE.

A high bank was used in one test (No. 1278). The other bank fire tests were made with a lower and smaller bank, and part of the fire was level.

M. P. 479—A 8 x 10½ 351 4-29-12

LOCOMOTIVE:
TYPE 2-8-0
CLASS H6b No. 2860
SHEET No. P-460

PENNSYLVANIA RAILROAD COMPANY
PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY
TEST DEPARTMENT

Bulletin No. 12

Bank Versus Level Firing ALTOONA, PA., 11-22-1912

TABLE 1

EVAPORATION AND SMOKE

WEST EUREKA NO.6 COAL

Test Number	Miles per Hour	Cut Off	throttle.	Boiler Pressure Avg.	Equivalent Evaporation From and at 212°F. Per Sq.Ft. Heat Surf. Per Hour	Per Pound of Dry Coal	Relative Evap.in per cent Best Evap. equals100%	Carbon Monoxide in Gases Average	Smoke in percent Average	Kind of Fire
				1	2	3	4	5	6	7
1276	13	40	Full	197.4	10.84	8.33	91.8	0.35%	28	Level
1275	"	"	"	201.6	11.36	9.07	100.0	0.60	36	"
Average							95.9			
1277	"	"	"	202.0	11.07	9.04	99.7	0.95	28	Bank
Average							99.7			
PITTSBURGH COAL COMPANY COAL										
1285	13	40	Full	202.3	10.88	8.68	91.9	0.10	24	Level
1288	"	"	"	201.0	10.86	9.17	97.0	—	32	"
1284	"	"	"	203.3	11.08	9.18	97.1	—	28	"
Average							95.3			
1286	"	"	"	203.3	11.09	8.66	91.6	0.35	28	Bank
1287	"	"	"	202.9	11.04	9.45	100.0	0.10	24	"
Average							95.8			

SHEET No. P-460

Table 1.

EVAPORATION AND SMOKE.

The tests in this table were made at 13 miles per hour.

Column 4 shows a comparison based upon evaporation per pound of coal.

From this standpoint the bank fire is the best.

M. P. 479—A

8 x 10½
351 4-29-12

LOCOMOTIVE:
TYPE 2-8-0
CLASS H6b NO. 2860

SHEET NO. P-461

Bank Versus Level Firing

PENNSYLVANIA RAILROAD COMPANY
PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY
TEST DEPARTMENT

Bulletin NO. 12

ALTOONA, PA. 11-15-1912

TABLE 2

EVAPORATION AND SMOKE

PITTSBURGH COAL COMPANY COAL.

Test Number	Miles per Hour	Cut off	throttle.	Boiler Pressure Avg.	Equivalent Evaporation From and at 212°F. Per Sq.Ft. Heat Surf. Per Hour	Equivalent Evaporation From and at 212°F. Per Pound of Dry Coal	Relative Evap. in per cent Best Evap. equals 100%	Carbon Monoxide in Gases Average	Smoke in percent Average	Kind of Fire
				1	2	3	4	5	6	7
1279	17	45	Full	197.7	14.89	7.35	83.2%	1.05%	48	Level
1283	"	"	"	199.7	14.85	7.72	87.4	1.30	42	"
1289	"	"	"	200.3	14.59	8.07	91.4	0.15	30	"
1290	"v	"	"	198.4	14.59	8.14	92.2	0.35	38	"
1293	"	"	"	197.3	14.29	8.53	96.6	0.80	34	"
1281	"	"	"	202.0	15.07	8.57	97.1	0.45	40	"
Average							91.3			
1278	"	"	"	193.5	14.21	6.89	*78.0	0.30	52	Bank
1292	"	"	"	198.7	14.66	7.82	88.6	0.85	42	"
1282	"	"	"	200.5	14.88	7.99	90.5	0.70	46	"
1280	"	"	"	201.8	15.07	8.16	92.4	0.45	50	"
1291	"	"	"	200.5	14.51	8.83	100.0	0.00	28	"
Average							89.9			
Average							∅ 92.8			

* 3-1/2 Foot Bank; the other tests are with an 1-1/2 Foot Bank.

∅ Omitting Test 1278 which has an excessively high bank.

SHEET NO. P-461

Table 2.

EVAPORATION AND SMOKE.

These tests were made at 17 miles per hour. If test No. 1278 (the real bank fire) is included, the average results for the bank fire are low.

heating surface per hour. The tests in Table 2 were run at a higher speed, 17 miles per hour and 45 per cent. cut-off, giving an evaporation of between 14 and 15 pounds of water per square foot of heating surface per hour.

15. These conditions did not make a very heavy demand upon the boiler for steam with these coals, as with the Eureka No. 6 coal we have obtained in other tests on the Plant an equivalent evaporation of 16½ pounds of water per square foot of heating surface per hour.

16. In column 4 of Tables 1 and 2 a comparison is made between the evaporation obtained by the different firemen. The highest evaporation for each group of tests is taken at 100 per cent.

17. Considerable differences are shown between the level fire firemen. It is very clear too, that the second test made by some of the men shows a very decided improvement over the first trial on the Test Plant.

18. In the case of fireman B1, with a bank fire, in test No. 1278, an evaporation of 6.89 pounds per pound of coal is shown, while on the next test, No. 1282, made by the same fireman, an evaporation of 7.99 pounds was obtained, an increase of about 14 per cent. and a saving of 961 pounds of coal in the second test. This would be a saving of about 2800 pounds over a 100 mile division.

Temperature Near Firedoor.

19. At a point near the firedoor a thermometer was suspended and observations of the temperature were made for each kind of firing, with the following results:

In test No. 1283, level fire, the temperature was	117° F.
" " " 1281, " " " " "	114° F.
Average	116°
In test No. 1282, bank fire, the temperature was	104° F.
" " " 1280 " " " " "	94° F.
Average	99°

There is here an average difference of 17 degrees between the bank and level fire.

Evaporation Per Pound of Coal.

20. On diagrams Fig. 4 and Fig. 5 the results of the tests are plotted to show the evaporation per pound of coal.

21. In the tests at 100 revolutions per minute the range of coal fired per square foot of grate is from 85 to over 105 pounds. The best results, or highest evaporation per pound of coal, are for the bank fire as fired by fireman B2. These tests are Nos. 1287 and 1291, and it will be noted that they were the last tests fired by this fireman, showing that this fireman improved in his firing by experience at the Plant. Fireman T1 and T2 in addition to their road firing had had considerable experience at the Plant, firing, between them, seventy-five tests, and the results of their work with the level fire are very close together. At 100 revolutions per minute, the difference in the evaporation per pound of coal between the tests Nos. 1281 and 1293, by these two firemen, is but four-hundredths of a pound. At 80 revolutions per minute, fireman T1 duplicates his two tests, Nos. 1275 and 1288, within one-tenth of a pound.

Smoke.

22. Observations of the smoke by the Ringelmann method were made at 10 minute intervals during each test, and the results are conflicting. (See Tables 1 and 2.) With Eureka coal at 13 miles per hour the level fire shows the most smoke. At the same speed and Pittsburgh coal the level fire again shows the most smoke. At 17 miles per hour with Pittsburgh coal the bank fires show the most smoke.

Gas Analysis.

23. The amount of carbon monoxide (CO) in the smokebox gases is dependent upon the completeness of the combustion, a large amount of CO indicating insufficient air supply and consequent incomplete combustion.

24. An inspection of the smokebox gas analysis does not show any marked difference between the two methods of firing. The least quantity of CO was obtained in bank fire test No. 1291.

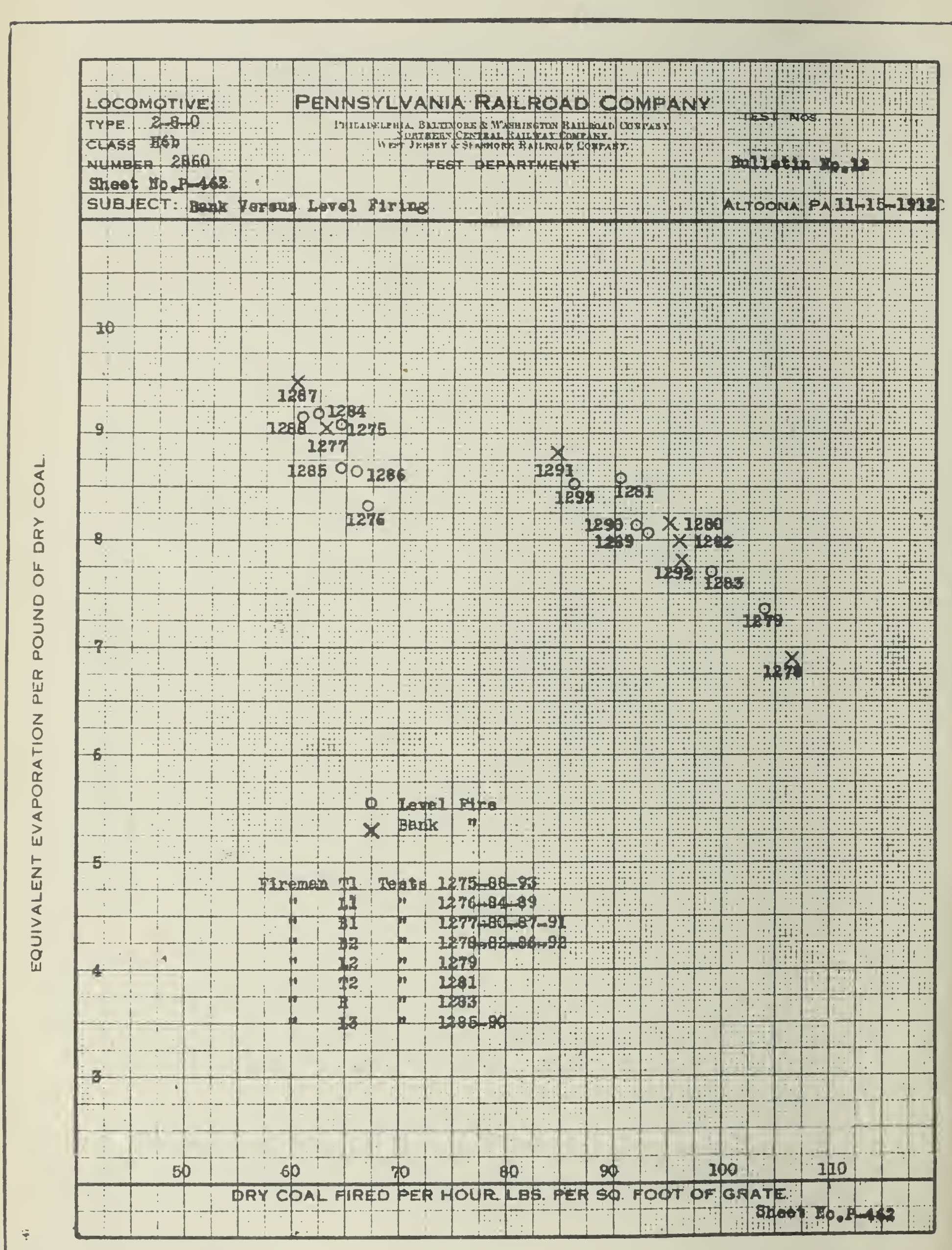


Fig. 4.

EVAPORATION PER POUND OF COAL AND RATE OF FIRING.

The test number is shown for each point. The results are influenced more by the skill of the fireman than by the method of firing.

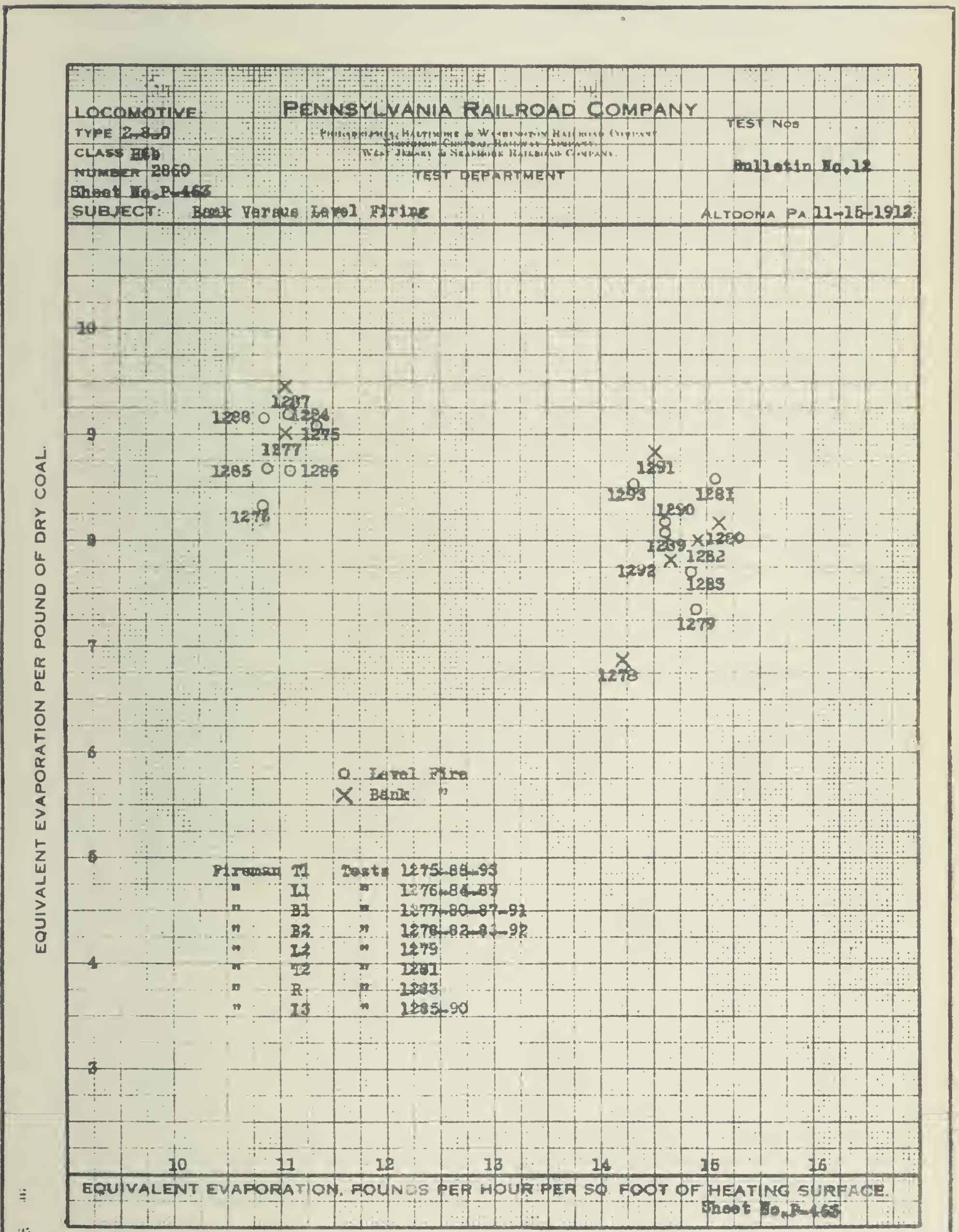


Fig. 5.

EVAPORATION PER POUND OF COAL AND RATE OF EVAPORATION.

Under the same conditions of running, there is much difference in the results with the different firemen regardless of the method of firing.

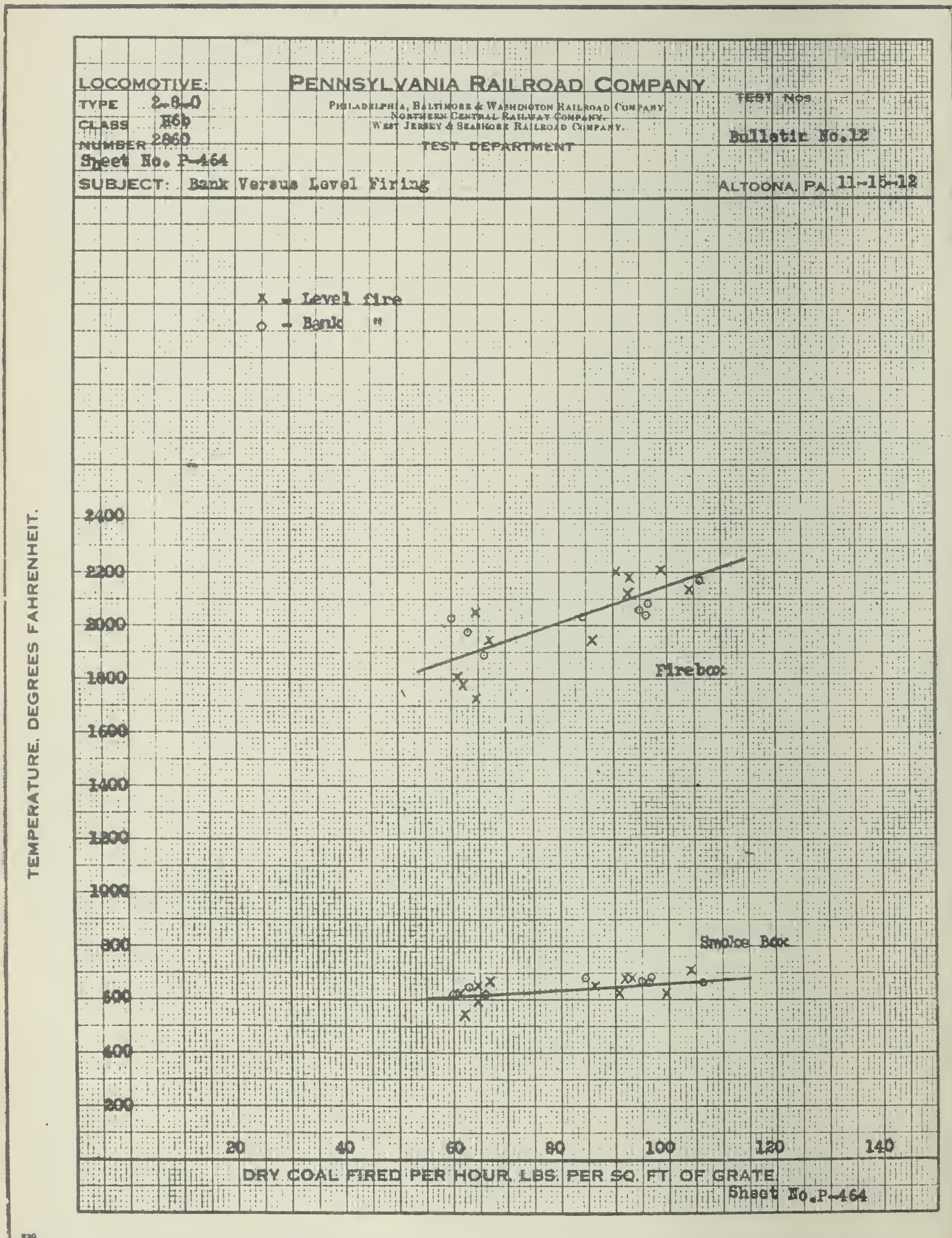


Fig. 6.

TEMPERATURES IN FIREBOX AND IN SMOKEBOX.

There is no apparent difference in temperature due to the method of firing.

Draft and Thickness of Fire.

25. The intensity of the draft at any speed and cut-off depends upon the thickness of the fire, and as the draft does not seem to have been affected by the method of firing, we may assume that the average thickness was the same in both the level and bank firing. The reason for the draft not being greater in test No. 1278, where a thick fire was carried at the back end, is that the fire was very thin in front and most of the air supply for the fire came through that portion of the grate.

Conclusions.

26. Of the two methods of firing, the results for the bank firing, as practiced at the Locomotive Test Plant during these tests, show a slightly higher evaporation of water per pound of coal. This is based on the results where a short bank was used. The large bank will be referred to later. The result in favor of the bank firing is due, possibly, more to the skill of the fireman than to the methods used. It would, therefore, seem safe to conclude that the amount of coal used with the low bank fire and with the level fire are the same.

27. If, however, the method of firing as practiced by fireman B1 in test No. 1278 is followed, the results are much less satisfactory than with the level fire. As the bank firing employed in test No. 1278 was used in the first test with a coal from the Lines West of Pittsburgh, it would appear that the size of the bank and the method of firing with it was the style of the bank fire that had been claimed to be more economical than the level fire. This method of bank firing is undoubtedly proved to be far from economical as compared with level firing, and the fact that fireman B1, who formerly advocated this method of firing, changed to the small form of bank after seeing the results, seems to be good evidence that the large bank, as first tried, was in his estimation not to be compared in economy with level firing.

28. It should be emphasized particularly that in speaking of bank firing as a method, the size of the bank which is to be employed must be clearly understood. The general statement that bank firing and level firing can be placed on a par, so far as economy in fuel is concerned, is misleading, unless a description of the bank method of firing is given.

29. The idea of the larger bank seems to be that it forms some protection for the fireman against the heat radiated through the firedoor and permits the firing to be done largely at the back end of the firebox, the coal or partly consumed coal working its way forward. It is this method of bank firing which has been shown to be uneconomical.

31. The method of bank firing with the low bank does not require all the coal to be fired at the back end, but requires firing in much the same way as with the level fire. The temperature near the firedoor from this form of bank has been shown to be from 10 to 23 degrees Fahrenheit less than with the level fire.

32. These trials were made on a single locomotive, one having a wide grate and a comparatively shallow firebox or a firebox in which the firedoor and lower tubes are, comparatively, near the grate. With a very deep and narrow firebox the conclusions probably do not apply, neither do they apply to all coals. It is assumed that they do apply to the great majority of locomotives on our own lines.

33. Unless the bank is high it does not protect the fireman from the heat of the fire to any great extent, and when it is high enough for this purpose, or when it extends above the top of the firedoor, very poor results are obtained from the boiler. With the bank extending above the door opening the firing must of necessity be performed in a haphazard manner, as the surface cannot be seen.

Recommendations.

34. We recommend that the instructions to firemen to fire by the level fire method be continued in force (Par. 11 and 28, and Par. 5 Circular 81A, Bulletin 16).

C. D. YOUNG,
Engineer of Tests.

Approved:
J. T. WALLIS,
Genl. Supt. Motive Power.

Test Department,
Altoona, Penna.
November 15, 1912.

M. P. 894A
8 x 10½

7 6 1907

Pennsylvania Railroad Company

Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company

TEST DEPARTMENT

Average Results of Locomotive Tests

LOCOMOTIVE:
TYPE 2-8-0
CLASS H6b
NUMBER 2860

TEST NOS., 1275 to 1293

SUBJECT: Bank Versus Level Firing

ALTOONA, PA., 9-5-1908

	Driving Wheels	
1	Number of Pairs	4
2	Approx. Diameter, inches	56
	Engine Truck Wheels	
14	Number	2
15	Diameter, inches	30
	Trailing Wheels	
16	Diameter, inches	—
	Wheel Base, Feet	
17	Driving Wheel Base	16.25
18	Total Wheel Base	24.84
19	Gage of Wheels	4.75
	Weight of Engine with Water at 2d. Gage Cock and Normal Fire, Pounds	
20	On Truck	21667
21	" 1st Drivers	45667
22	" 2d "	42583
23	" 3d "	47500
24	" 4th "	40850
25	" 5th "	—
26	" Trailers	—
27	Total	198267
28	" on Drivers	176600
	Cylinders	
	Diam. and Stroke, H P	22 x 28
	" " " L. P	—
	Clearance in per cent. of Piston Displacement	
40	H. P. Right, Head End	12.5
41	" " Crank "	10.7
42	" Left, Head "	12.2
43	" " Crank "	10.8
44	L. P. Right, Head "	—
45	" " Crank "	—
46	" Left, Head "	—
47	" " Crank "	—
	Receiver, Cubic Feet	
48	Volume Right Side	—
49	" Left "	—
	Steam Ports, Inches	
50	H. P. Admission, Length	30
51	" " Width	2
58	L. P. " Length	—
59	" " Width	—
66	H. P. Exhaust, Length	No Port
67	" " Width	" "
70	L. P. " Length	—
71	" " Width	—

	Piston Rods, Diameter Inches	
74	High Pressure	4
76	Low "	—
	Tail Rods, Diameter, Inches	
78	High Pressure	—
80	Low "	—
	Valves	
82	Type	Piston
83	Design	Amer.Bal.Valve Co.
84	Per Cent. Balanced	100
85	Type of Valve Motion	Walschaerts
	Greatest Valve Travel	
86	High Pressure, inches	6.25
88	Low " "	—
	Steam Lap of Valve	
90	High Pressure, inches	.91
94	Low " "	—
	Exhaust Lap of Valve	
98	High Pressure, inches	.06
102	Low " "	—
	Boiler	
113	Type	Belpaire, wide firebox
114	Outside Diam. 1st Ring	71.16
	Tubes	
115	Number	373
116	Outside Diam., inches	2
	Pitch "	2.6875
118	Length Between Tube Sheets, inches	164.28
119	Total Fire Area, sq ft.	6.23
124	Boiler Pressure, pounds	205
	Superheater	
125	Number of Tubes	—
126	Outside Diam. " inches	—
128	Length of " "	—
	Firebox, Inside, Inches	
132	Length	118.32
133	Width	65.04
137	Air Inlets to Ashpan, sq. ft.	7.56
	Grates	
144	Type	Rocking Finger
145	Grate Area, sq. ft.	48.66
146	Area of Dead Grates	0

	Heating Surface, Square Feet	
164	Of the Tubes, Water Side	2673.68
155	" " " Fire "	2339.23
156	" " Firebox, " "	166.06
157	" " Superh'r, " "	—
*158	Total, Based on " "	2505.29
159	" " " " " of Firebox and Water Side of Tubes	2839.74
	Boiler Volume with water surface at level of 2d gage cock	
160	Water Space, cu. ft.	349.7
161	Steam " "	83.1
	Exhaust Nozzle	
162	Double or Single	Single
163	Size, inches	5.63
167	Area, sq. inches	24.89
	Reverse Lever	
168	H. P. Notches Forward of Center	22
169	L. P. Notches Forward of Center	—
	Ratios	
171	Heating Surface (158) to Grate Area (145)	51.49
172	Fire Area Thru Tubes (119) to Grate Area (145)	.13
173	Firebox Heating Surface (156) to Grate Area (145)	3.41
174	Tube Heating Surface (155) to Fire Box Heating Surface (156)	14.09

*USED IN CALCULATIONS

Table 3.
DIMENSIONS OF CLASS H6b LOCOMOTIVE 2860 USED IN BANK FIRE TEST.

M. P. 394 A—Sixth Sheet
8 x 10½

11-9-10

PENNSYLVANIA RAILROAD COMPANY

Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company

TEST DEPARTMENT

AVERAGE RESULTS OF LOCOMOTIVE TESTS

LOCOMOTIVE:
TYPE 2-8-0
CLASS H8b
NUMBER 2860

FUEL: West Eureka and Pittsburgh Coal

SUBJECT: Bank versus Level Firing

ALTOONA, PA., 8-24-1908

TEST NUMBER	RUNNING CONDITIONS: TEST DESIGNATION	Duration of Test, Hours	Miles per Hour	Throttle Opening, Full or Partial	Actual Cut-off Per Cent., H. P. Cylinders	Method of Firing	BOILER PERFORMANCE: Pressure in Boiler, Lbs. per Sq. Inch	Draft in Smoke Box, Inches of Water	Draft in Ash Pan, Inches of Water	Calorific Value of Dry Fuel, B. T. U. per Lb.	Cinders Collected in Smoke Box, Pounds per Hour
	R. P. M. Cut-off Throttle	196	199	203	268 to 271		217	222	225	248	238
1275	80-40-F	2.5	13.36	Full		Level	201.6	3.5	0.1	13743	70
1276	80-40-F	2.5	13.36	"		"	197.4	3.5	0.1	13743	108
1277	80-40-F	2.5	13.36	"		Bank	202.0	3.9	0.1	13743	126
1284	80-40-F	1.25	13.30	Full		Level	203.0	3.5	0.1	12364	58
1285	80-40-F	2.50	13.31	"		"	202.3	3.6	0.1	12364	33
1286	80-40-F	2.50	13.31	"		Bank	203.3	3.6	0.1	12364	31
1287	80-40-F	2.50	13.31	"		"	202.9	3.6	0.1	12364	23
1288	80-40-F	2.50	13.31	"		Level	201.0	3.5	0.1	12364	18
1289	100-45-F	2.00	16.64	"		"	200.3	5.1	0.2	12364	44

TEST NUMBER	BOILER PERFORMANCE: Dry Fuel Fired per Hour, Pounds	Dry Fuel per Hour, Pounds per Sq. Ft. of Grate	Water Delivered to Boiler, Pounds per Hour	Equivalent Evaporation from and at 212° F., Pounds: Per Hour	Per Hour per Sq. Ft. of Fire Heating Sur.	Per Pound of Dry Fuel	Boiler Horse Power (34½ U. of E.)	Efficiency of Boiler, Based on Fuel		ENGINE PERFORMANCE: Pressure in Branch Pipe, Pounds per Sq. In.	Superheat in Branch Pipe Degrees F.
	338	339	340	344	345	347	349	350		220	230
1275	3135	64.43	23938	23449	11.36	9.07	824.6	68.74			
1276	3259	66.98	22865	27162	10.84	8.33	787.3	58.54			
1277	3070	63.09	23334	27743	11.07	9.04	804.2	63.38			
1284	3024	62.15	23306	27749	11.08	9.18	804.3	71.71			
1285	3140	64.53	22879	27265	10.88	8.68	790.3	67.80			
1286	3207	65.91	23309	27787	11.09	8.66	805.4	67.65			
1287	2928	60.18	23223	27670	11.04	9.45	802.0	73.81			
1288	2966	60.96	22828	27202	10.86	9.17	788.5	71.63			
1289	4531	93.12	30667	36546	14.59	8.07	1059.3	63.04			

TEST NUMBER	ENGINE PERFORMANCE: Dry Steam to Engines, Pounds per Hour	Indicated Horse Power	Dry Fuel per Indicated Horse Power Hour, Pounds	Dry Steam per Indicated Horse Power Hour, Pounds		LOCOMOTIVE PERFORMANCE: Drawbar Pull, Pounds	Dynamometer or Drawbar Horse Power	Dry Fuel per Dynamom. Horse Power Hour, Pounds	Dry Steam per Dynamom. Horse Power Hour, Pounds	Machine Efficiency of Locomotive, Per Cent.	Thermal Efficiency of Locomotive, per Cent., (Based on Fuel)	
	214	379	380	381		265	383	384	385	398	399	
1275	23648					22279	794.0	4.9	29.8		4.7	
1276	22579					21521	767.0	4.3	29.4		4.4	
1277	23017					22310	795.1	3.9	29.0		4.8	
1284	22955					22536	802.2	3.8	28.6		5.5	
1285	22575					22170	790.1	4.0	28.6		5.2	
1286	22994					22522	802.7	4.0	28.7		5.2	
1287	22920					22192	790.9	3.7	26.0		5.6	
1288	22543					22276	793.9	3.7	28.4		5.5	
1289	30291					23343	1039.9	4.4	29.1		4.7	

Table 4.
RESULTS OF BANK AND LEVEL FIRE TESTS.

M. P. 394 A—Sixth Sheet
8 x 10½

11-9-10

PENNSYLVANIA RAILROAD COMPANY

Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company

TEST DEPARTMENT

LOCOMOTIVE:
TYPE 2-8-0
CLASS H6b
NUMBER 2860

FUEL: Pittsburgh Coal Co.

AVERAGE RESULTS OF LOCOMOTIVE TESTS

SUBJECT: Bank Versus Level Firing

ALTOONA, PA., 8-24-1908

TEST NUMBER	RUNNING CONDITIONS: TEST DESIGNATION	Duration of Test, Hours	Miles per Hour	Throttle Opening, Full or Partial	Actual Cut-off Per Cent., H. P. Cylinders	Method of Firing	BOILER PERFORMANCE: Pressure in Boiler, Lbs. per Sq. Inch	Draft in Smoke Box, Inches of Water	Draft in Ash Pan, Inches of Water	Calorific Value of Dry Fuel, B. T. U. per Lb.	Cinders Collected in Smoke Box, Pounds per Hour
	R. P. M. Cut-off Throttle	196	199	203	268 to 271		217	222	225	248	238
1290	100-45-F	2.00	16.64	Full		Level	198.4	5.3	0.2	12364	46
1291	100-45-F	2.00	16.64	"		Bank	200.5	5.6	0.1	12364	35
1292	100-45-F	2.00	16.64	"		"	198.7	5.4	0.2	12364	37
1293	100-45-F	2.00	16.64	"		Level	197.3	5.4	0.2	12364	45
1278	100-45-F	2.0	16.71	"		Bank	193.5	5.8	0.1	12447	94
1279	100-45-F	2.0	16.71	"		Level	197.7	5.7	0.1	12447	102
1280	100-45-F	2.0	16.71	"		Bank	201.8	5.8	0.2	12447	54
1281	100-45-F	2.0	16.71	"		Level	202.0	5.7	0.1	12447	20
1282	100-45-F	2.0	16.71	"		Bank	200.5	5.7	0.2	12281	48
1283	100-45-F	2.0	16.71	"		Level	199.7	5.5	0.2	12281	56

TEST NUMBER	BOILER PERFORMANCE: Dry Fuel Fired per Hour, Pounds	Dry Fuel per Hour. Pounds per Sq. Ft. of Grate	Water Delivered to Boiler, Pounds per Hour	Equivalent Evaporation from and at 212° F., Pounds: Per Hour	Per Hour per Sq. Ft. of Fire Heating Sur.	Per Pound of Dry Fuel	Boiler Horse Power (34½ U. of E.)	Efficiency of Boiler, Based on Fuel		ENGINE PERFORMANCE: Pressure in Branch Pipe, Pounds per Sq. In.	Superheat in Branch Pipe Degrees F.
	338	339	340	344	345	347	349	350		220	230
1290	4491	92.30	30668	36541	14.59	8.14	1059.2	63.58			
1291	4118	84.61	30478	36351	14.51	8.83	1053.7	68.97			
1292	4694	96.47	30807	36722	14.66	7.82	1064.4	61.09			
1293	4199	86.29	30056	35807	14.29	8.53	1037.9	66.63			
1278	5169	106.23	29955	35597	14.21	6.89	1031.8	53.46			
1279	5074	104.28	31375	37306	14.89	7.35	1081.4	57.03			
1280	4624	95.03	31738	37753	15.07	8.16	1094.3	63.32			
1281	4408	90.59	31747	37764	15.07	8.57	1094.6	66.50			
1282	4669	95.95	31343	37287	14.88	7.99	1080.8	62.83			
1283	4823	99.12	31297	37213	14.85	7.72	1078.6	60.71			

TEST NUMBER	ENGINE PERFORMANCE: Dry Steam to Engines, Pounds per Hour	Indicated Horse Power	Dry Fuel per Indicated Horse Power Hour, Pounds	Dry Steam per Indicated Horse Power Hour, Pounds		LOCOMOTIVE PERFORMANCE: Drawbar Pull, Pounds	Dynamometer or Drawbar Horse Power	Dry Fuel per Dynamom. Horse Power Hour, Pounds	Dry Steam per Dynamom. Horse Power Hour, Pounds	Machine Efficiency of Locomotive, Per Cent.	Thermal Efficiency of Locomotive, per Cent., (Based on Fuel)	
	214	379	380	381		265	383	384	385	398	399	
1290	30297					23255	1036.0	4.3	29.3		4.8	
1291	30100					23028	1025.9	4.0	29.3		5.1	
1292	30434					23093	1028.8	4.6	29.6		4.5	
1293	29691					22897	1020.1	4.1	29.1		5.0	
1278	29593					22191	988.6	5.2	29.9		3.9	
1279	30995					22558	1005.0	5.1	30.8		4.1	
1280	31354					23431	1045.9	4.4	30.0		4.6	
1281	31345					23185	1032.9	4.3	30.4		4.7	
1282	30952					23220	1034.5	4.5	29.9		4.6	
1283	30862					23085	1028.4	4.7	30.0		4.4	

Table 5.
RESULTS OF BANK AND LEVEL FIRE TESTS

GRAPHICAL LOG OF TEST.

The following diagrams show the boiler pressure, speed, drawbar pull and weight of coal and water for each ten minute interval of the test. A diagram is drawn for each test and is on file with the Test Plant records. A few representative diagrams are shown here.

M. P. Experimental D-1

12 9 1911
8 x 10½

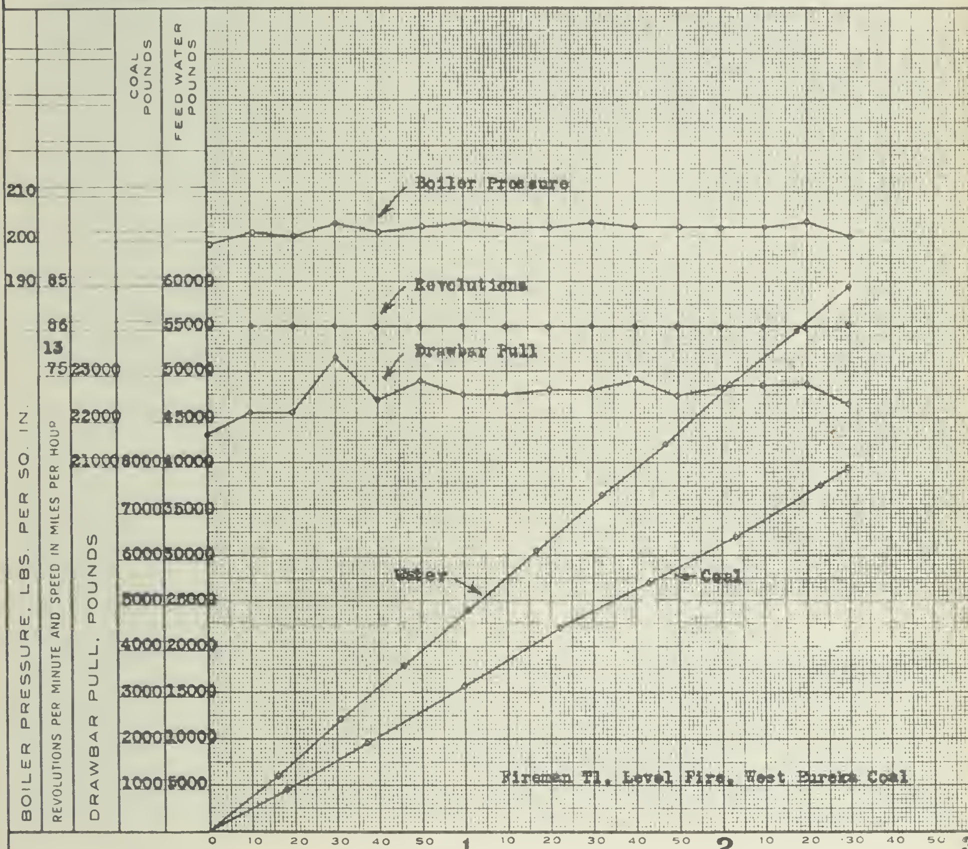
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO P-465 TEST DEPARTMENT Bulletin NO. 12

GRAPHICAL LOG OF LOCOMOTIVE TEST

Bank versus level Fire. ALTOONA, PA. 8-17-1908



⁘ UPPER FIGURES R. P. M.
LOWER FIGURES APPROX.
SPEED IN MILES PER HOUR

LENGTH OF TEST— MINUTES AND HOURS

LOCOMOTIVE
TYPE 2-8-0
CLASS H6b
NUMBER 2860

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
13.36	80	40	Full	7.57

TEST NO. 1275

SHEET NO. P-465

M. P. Experimental D-1

12 9 1911
8 x 10½

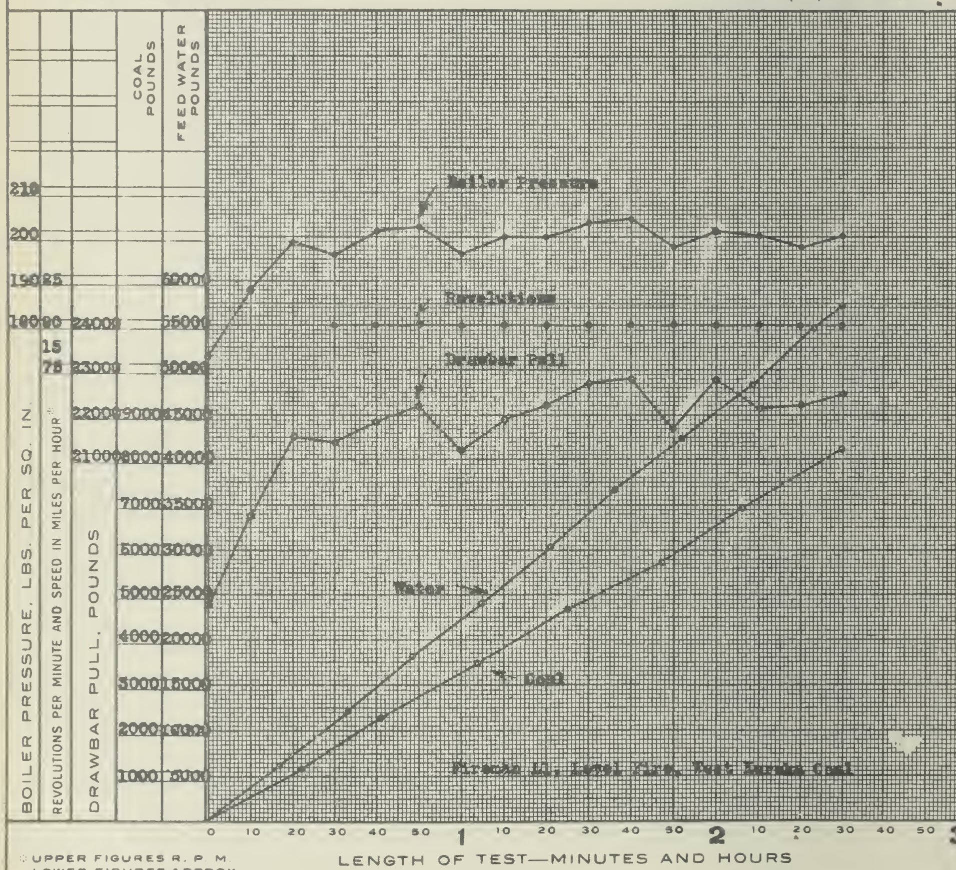
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-466 TEST DEPARTMENT Bulletin NO. 12

GRAPHICAL LOG OF LOCOMOTIVE TEST

Bank Versus Level Fire ALTOONA, PA., 8-18-1908



* UPPER FIGURES R. P. M.
LOWER FIGURES APPROX.
SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 2-8-0
CLASS H6b
NUMBER 2860

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
13.36	80	40	Full	6.96

TEST NO. 1276

SHEET NO. B-466

M. P. Experimental D-1

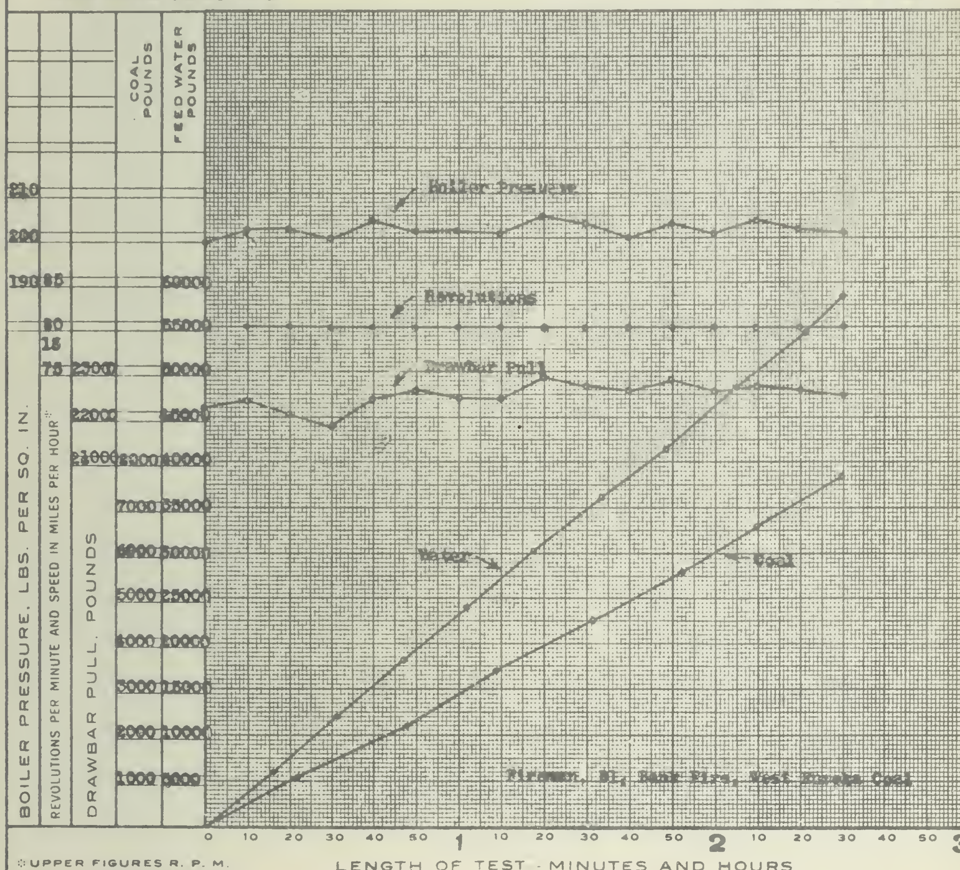
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-467 TEST DEPARTMENT Bulletin NO 12

GRAPHICAL LOG OF LOCOMOTIVE TEST

Bank versus Level Fire ALTOONA, PA., 8-18-1908



*UPPER FIGURES R. P. M.
LOWER FIGURES APPROX.
SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 2-8-0
CLASS H6b
NUMBER 2860

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
13.36	80	40	Full	7.15

TEST NO. 1277

SHEET NO. P-467

M. P. Experimental D-1

12 9 1911
8 x 10½

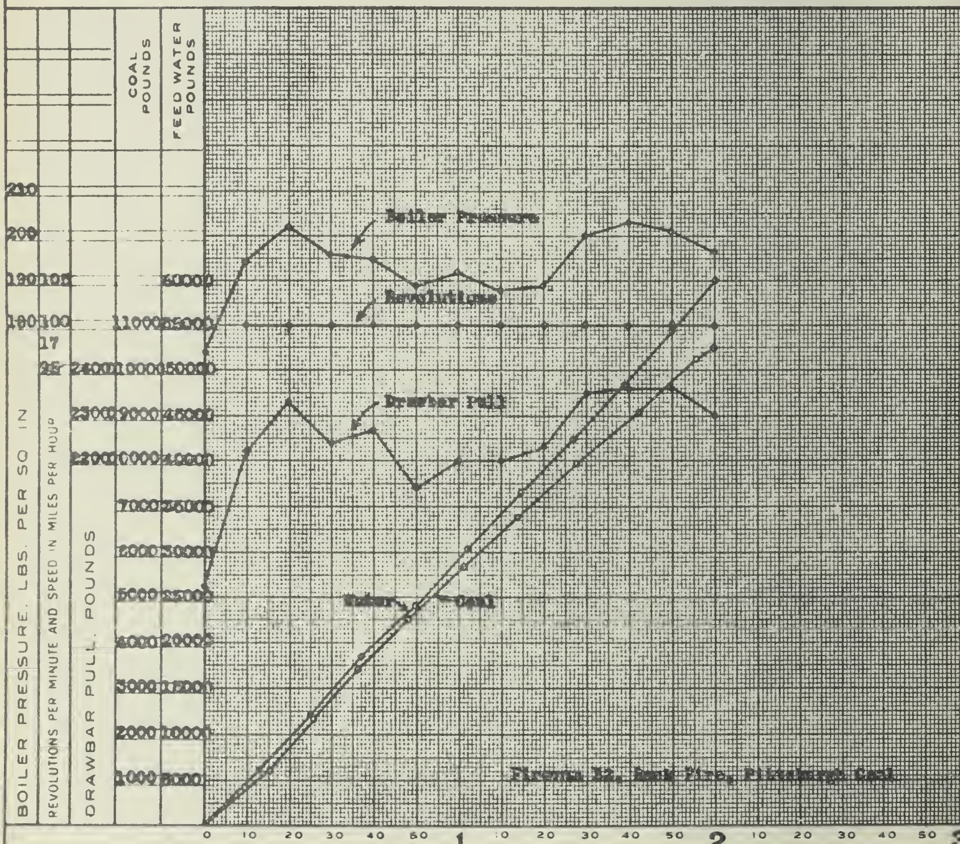
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-468 TEST DEPARTMENT Bulletin NO. 12

GRAPHICAL LOG OF LOCOMOTIVE TEST

Bank versus Level Fire ALTOONA, PA., 8-19-1908



UPPER FIGURES R. P. M.
LOWER FIGURES APPROX. SPEED IN MILES PER HOUR

LENGTH OF TEST—MINUTES AND HOURS

LOCOMOTIVE
TYPE 2-8-0
CLASS H6b
NUMBER 2860

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
16.71	100	45	Full	5.69

TEST NO. 1278

SHEET NO. P-468

M P. Experimental D-1

12 9 1911
8 x 10½

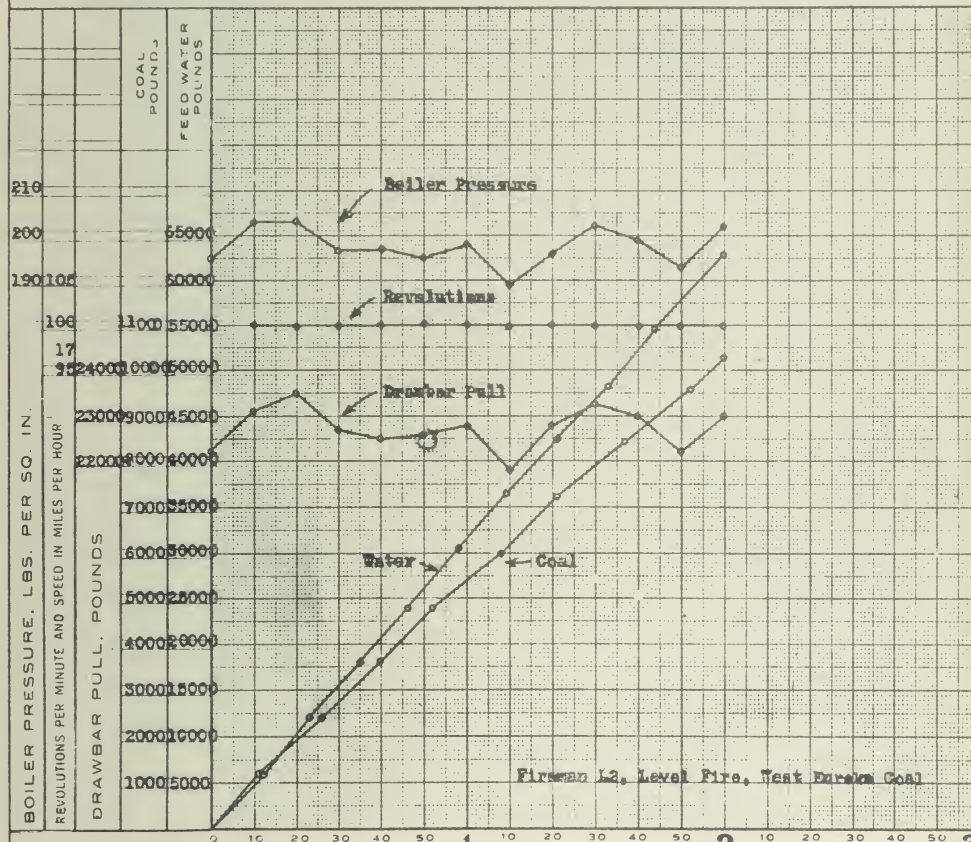
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO P-469 TEST DEPARTMENT Bulletin NO 12

GRAPHICAL LOG OF LOCOMOTIVE TEST

Bank versus Level Fire. ALTOONA, PA., 8-20-1908



UPPER FIGURES R. P. M.
LOWER FIGURES APPROX.
SPEED IN MILES PER HOUR

LENGTH OF TEST MINUTES AND HOURS

LOCOMOTIVE
TYPE 2-8-0
CLASS H6b
NUMBER 2860

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent. H. P. Cylinder	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
16.71	100	45	Full	6.07

TEST NO. 1279

SHEET NO. P-469

M. P. Experimental D-1

12 9 1911
8 x 10½

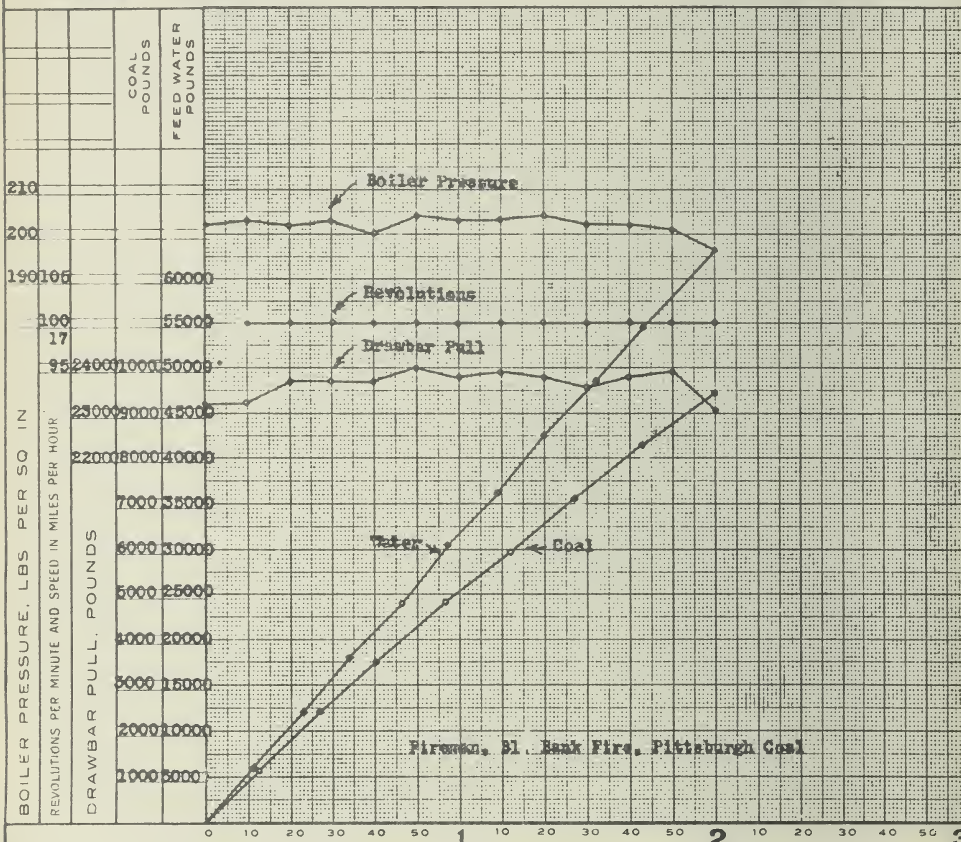
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-470 | TEST DEPARTMENT | Bulletin NO 12

GRAPHICAL LOG OF LOCOMOTIVE TEST

Bank versus Level Fire | ALTOONA, PA. 8-20-1908



UPPER FIGURES R. P. M.
LOWER FIGURES APPROX.
SPEED IN MILES PER HOUR

LENGTH OF TEST— MINUTES AND HOURS

LOCOMOTIVE
TYPE 2-8-0
CLASS H6b
NUMBER 2860

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
16.71	100	45	Full	6.74

TEST NO. 1280

SHEET NO. P-470

M. P. Experimental D-1

12 9 1911
8 x 10½

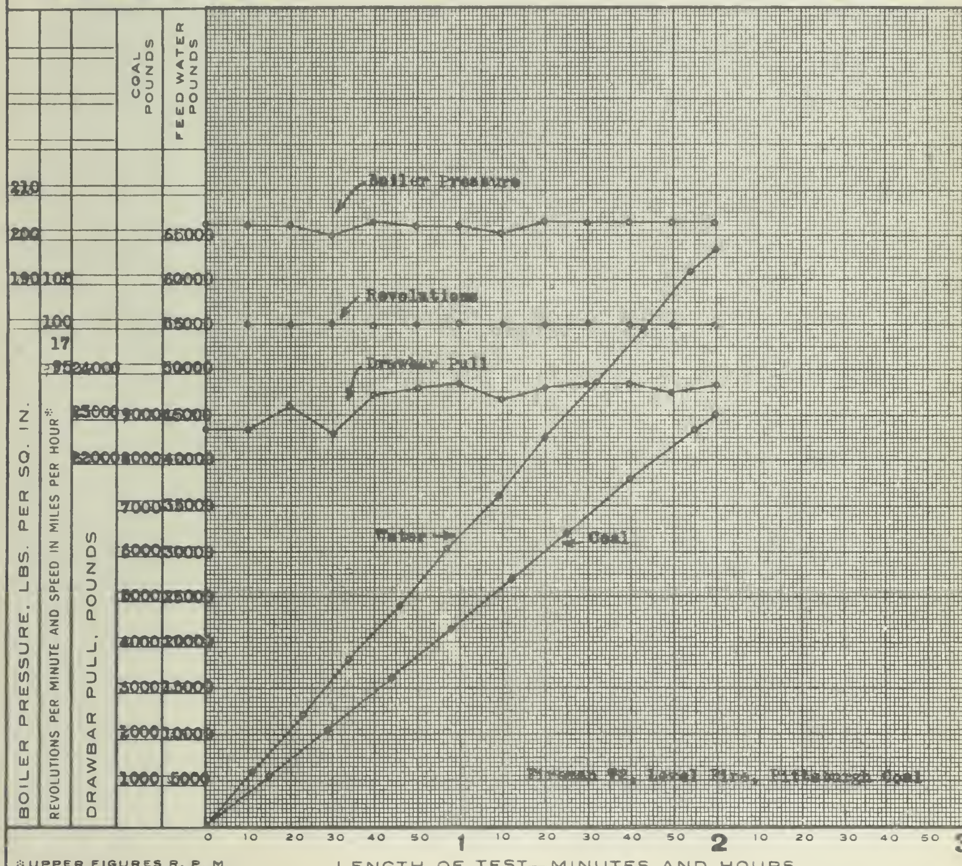
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-471 TEST DEPARTMENT Bulletin NO. 12

GRAPHICAL LOG OF LOCOMOTIVE TEST

Bank Versus Level Fire ALTOONA, PA., 8-21-1908



*UPPER FIGURES R. P. M.
LOWER FIGURES APPROX.
SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 2-8-0
CLASS H6b
NUMBER 2860

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
16.71	100	45	Full	7.15

TEST NO. 1281

SHEET NO. P-471

M. P. Experimental D-1

12 9 1911
8 x 10½

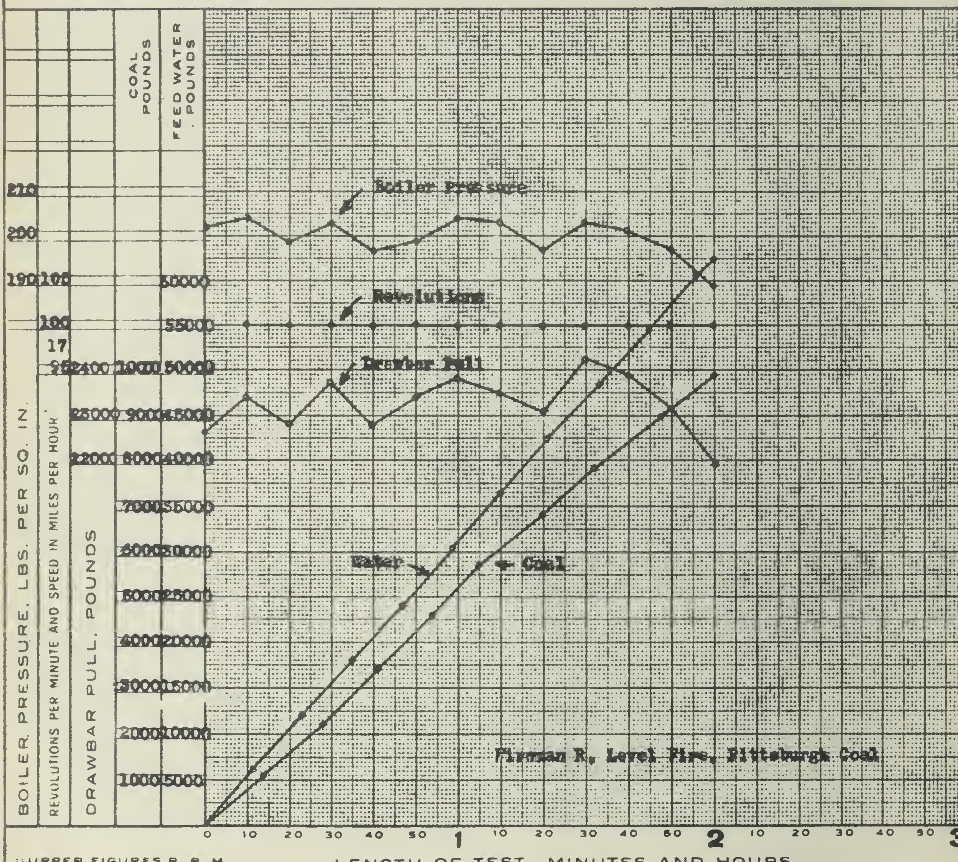
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. **P-472** TEST DEPARTMENT **Bulletin** NO. **12**

GRAPHICAL LOG OF LOCOMOTIVE TEST

Bank versus Level Fire. ALTOONA, PA., **8-22-1908**



*UPPER FIGURES R. P. M.
LOWER FIGURES APPROX.
SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE **2-8-0**
CLASS **H6b**
NUMBER **2860**

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
16.71	100	45	Full	6.33

TEST NO. **1283**

SHEET NO. **P-472**

M. P. Experimental D-1

12 9 1911
8 x 10½

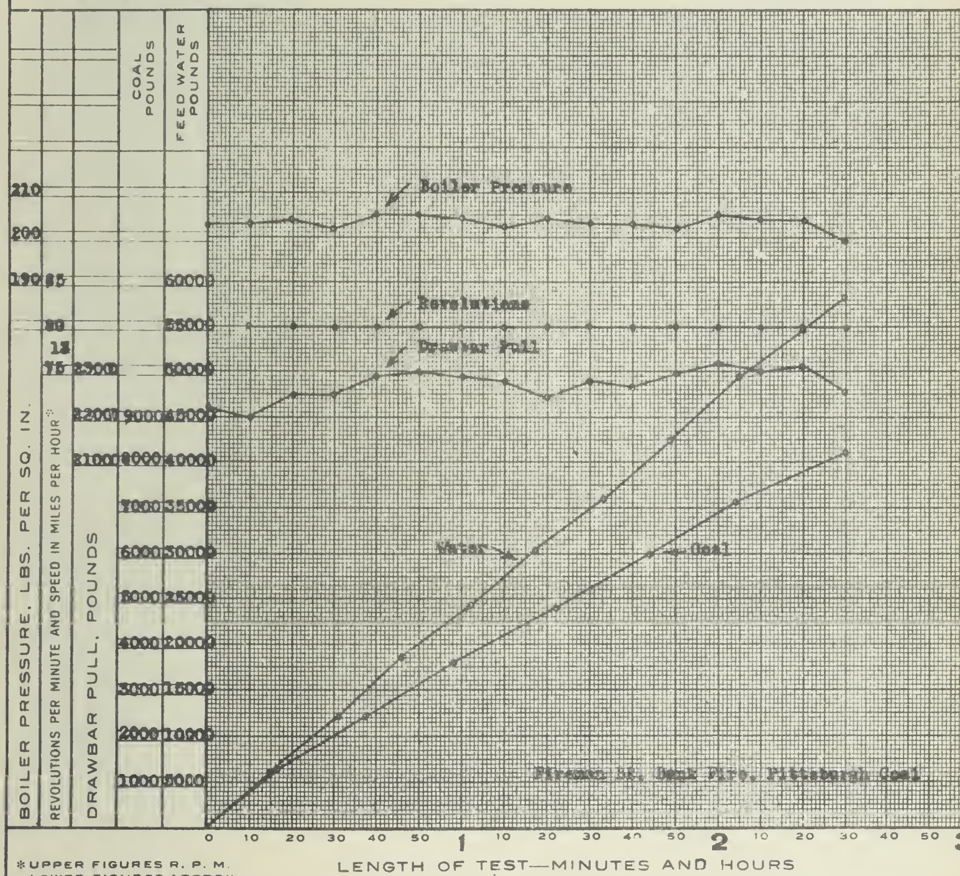
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-473 TEST DEPARTMENT Bulletin NO. 12

GRAPHICAL LOG OF LOCOMOTIVE TEST

Bank versus Level Fire. ALTOONA, PA., 9-1-1908



*UPPER FIGURES R. P. M.
LOWER FIGURES APPROX.
SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 2-8-0
CLASS H6b
NUMBER 2860

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
13.31	80	40	Full	7.11

TEST NO. 1286

SHEET NO. P-473

M. P. Experimental D-1

12 9 1911
8 x 10½

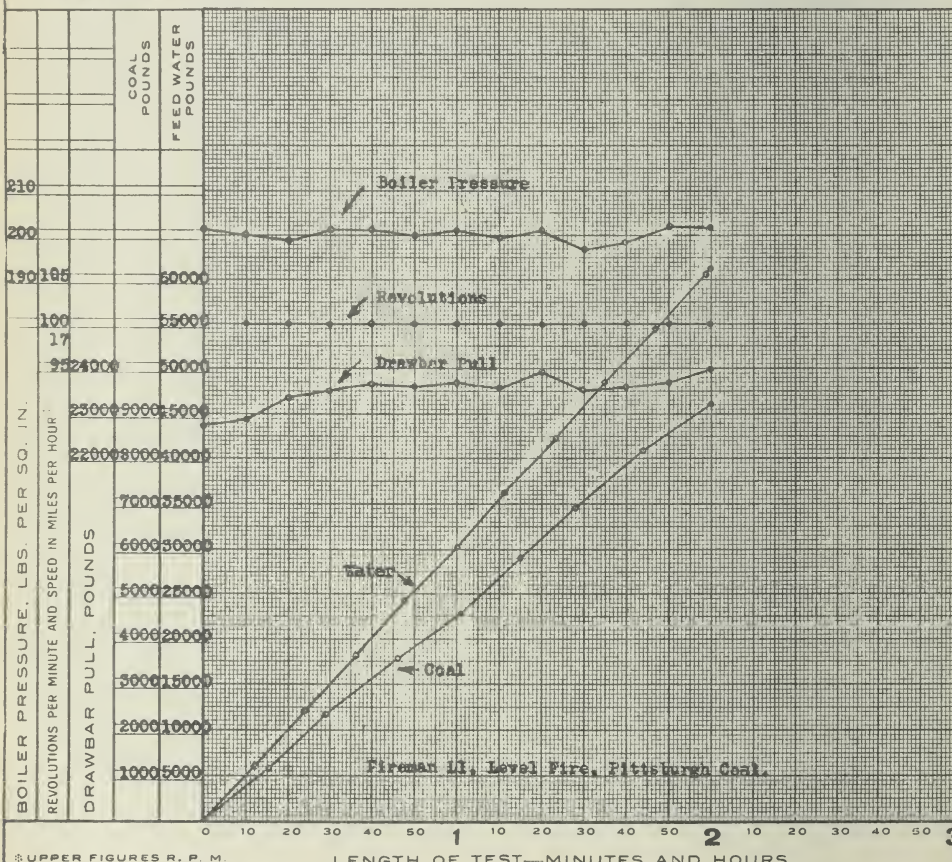
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY.
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-474 TEST DEPARTMENT Bulletin NO. 12

GRAPHICAL LOG OF LOCOMOTIVE TEST

Bank versus Level Fire ALTOONA, PA., 9-3-1908



* UPPER FIGURES R. P. M.
LOWER FIGURES APPROX.
SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 2-8-0
CLASS H6b
NUMBER 2860

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
16.64	100	45	Full	6.63

TEST NO. 1289

SHEET NO. P-474

M. P. Experimental D-1

12 9 1911
8 x 10½

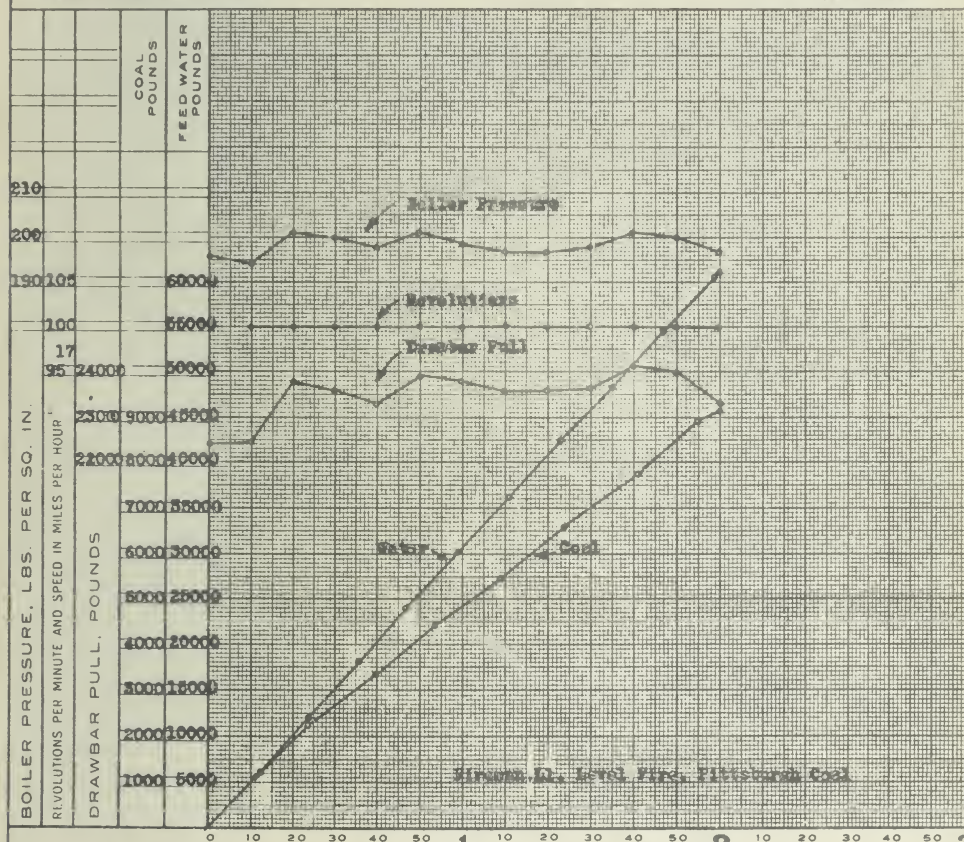
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-475 TEST DEPARTMENT Bulletin NO 12

GRAPHICAL LOG OF LOCOMOTIVE TEST

Bank versus Level Fire ALTOONA, PA., 9-3-1908



UPPER FIGURES R. P. M
LOWER FIGURES APPROX.
SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 2-8-0
CLASS H6b
NUMBER 2860

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
16.64	100	45	Full	6.69

TEST NO. 1290

SHEET NO. P-475

M. P. Experimental D-1

12 9 1911
8 x 10½

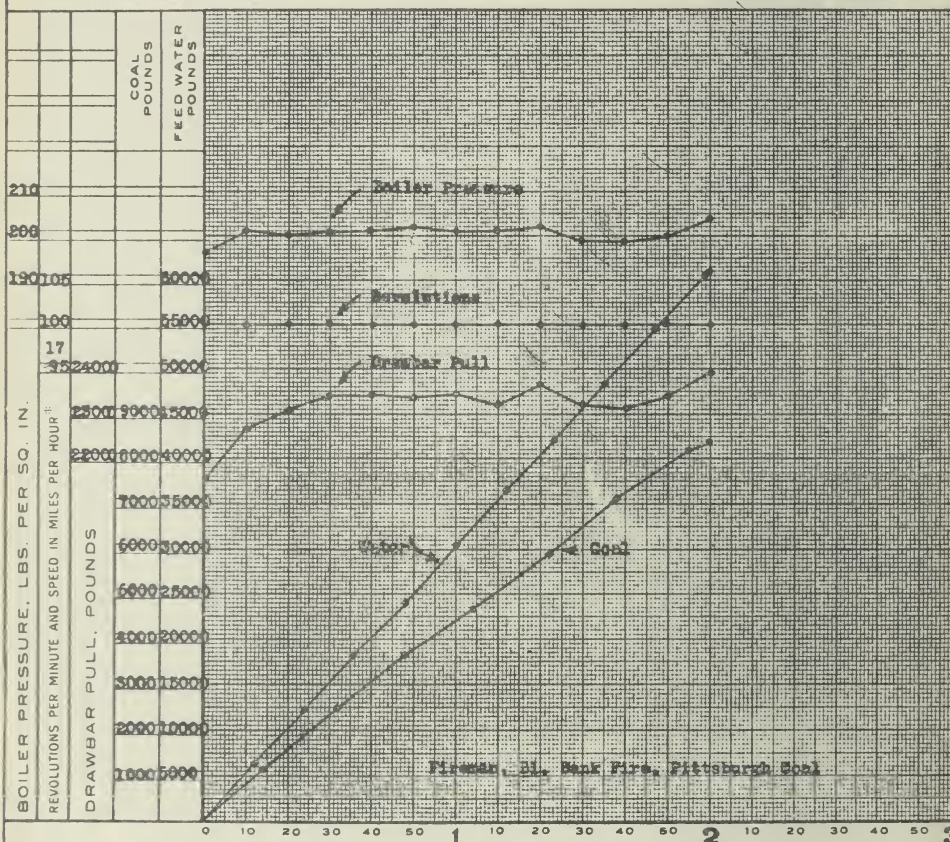
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-476 TEST DEPARTMENT Bulletin NO. 12

GRAPHICAL LOG OF LOCOMOTIVE TEST

Bank versus Level Fire ALTOONA, PA., 9-4-1908



* UPPER FIGURES R. P. M.
LOWER FIGURES APPROX.
SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 2-8-0
CLASS H6b
NUMBER 2860

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
16.64	100	45	Full	7.24

TEST NO. 1291

SHEET NO. P-476

M. P. Experimental D-1

12 x 1011
8 x 10½

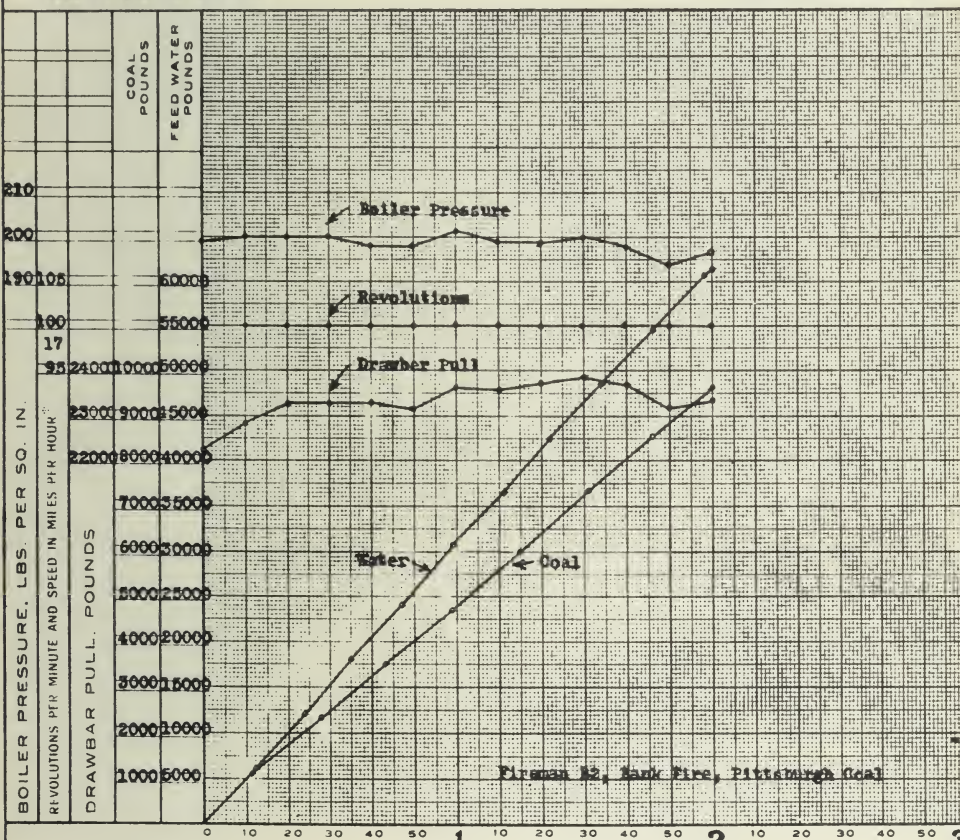
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-477 TEST DEPARTMENT Bulletin NO. 12

GRAPHICAL LOG OF LOCOMOTIVE TEST

Bank Versus Level Fire ALTOONA, PA. 9-4-1908



UPPER FIGURES R. P. M
LOWER FIGURES APPROX
SPEED IN MILES PER HOUR

LENGTH OF TEST—MINUTES AND HOURS

LOCOMOTIVE
TYPE 2-8-0
CLASS H6b
NUMBER 2860

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
16.64	100	45	Full	6.42

TEST NO. 1292

SHEET NO. P-477

M. P. Experimental D-1

12 9 1911
8 x 10½

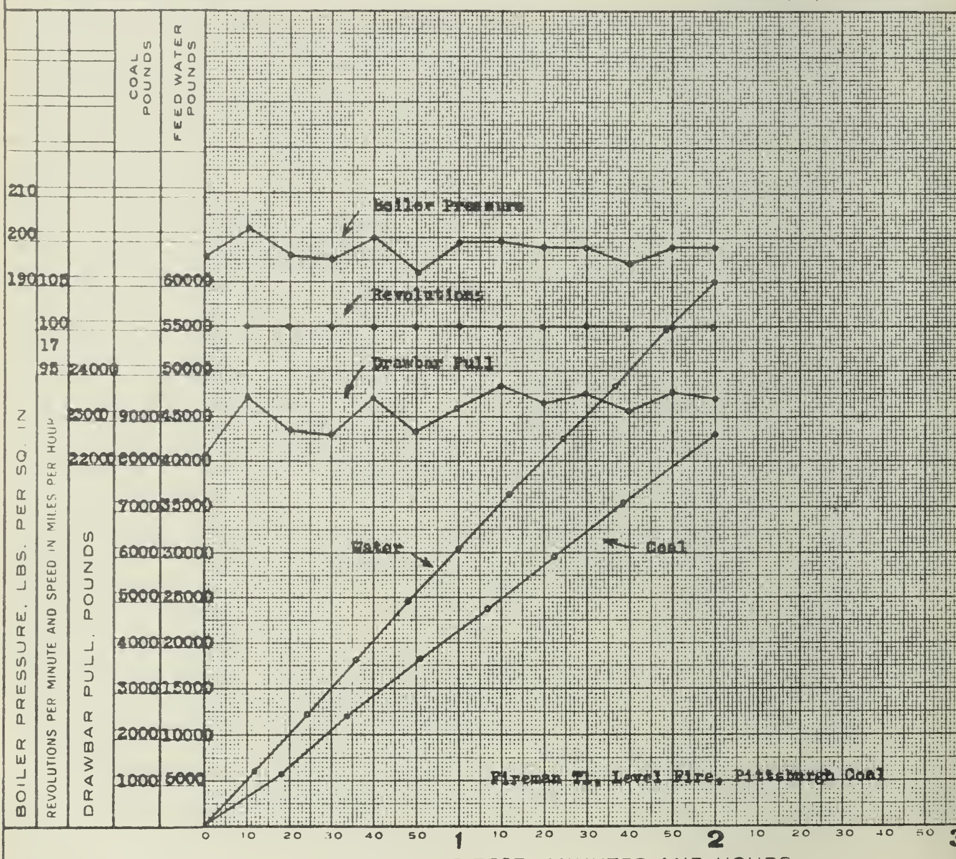
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-478 TEST DEPARTMENT Bulletin NO. 12

GRAPHICAL LOG OF LOCOMOTIVE TEST

Bank versus Level Fire ALTOONA, PA. 9-5-1908



UPPER FIGURES R. P. M
LOWER FIGURES APPROX.
SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 2-8-0
CLASS H6b
NUMBER 2860

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
16.64	100	45	Full	7.01

TEST NO. 1293

SHEET NO. P-478

PENNSYLVANIA RAILROAD COMPANY

Locomotive Testing Plant

AT

ALTOONA, PENNA.

BULLETIN No. 13 (Revised)

FORMERLY BULLETINS NOS. 17 AND 18

SMOKEBOX SUPERHEATER

1913

LOCOMOTIVE TESTING PLANT.

SMOKEBOX SUPERHEATER.

Conclusions and recommendations on pages 54 and 55.

TRIALS OF A SMOKEBOX OR WASTE GAS SUPERHEATER, THE RESULTS OF WHICH SHOW THAT THE ADVANTAGES OF THIS METHOD OF SUPERHEATING ARE NOT SUFFICIENT TO JUSITFY ITS FURTHER USE.

INTRODUCTION.

1. The hot waste gases discharged from the locomotive stack have always presented an opportunity for the introduction of some means of overcoming the loss of the heat that is in them, and one of these is the smokebox superheater.

2. The application of a superheater for this purpose, as here described, did not result in the realization of the benefits expected, as the saving by its use was offset by the disadvantages arising from its effect in checking the draft of the locomotive and making it impossible to develop the normal maximum boiler power.

3. The smokebox superheater must of necessity be one giving a low or moderate superheat (less than 100 degrees), on account of the comparatively confined space and the low temperature of the gases in the smokebox, which is from 500 to 700 degrees Fahrenheit.

4. The fact of the rather low temperature of the gases has lead to the suggestion of a lowering of the boiler pressure so that with a lower saturated steam temperature, a greater degree of superheat would be possible Further justification of this course was found in the lessened boiler maintenance cost, it was expected would follow the use of a low boiler pressure.

5. There is a very general agreement that the advantages of superheating are largely due to a decreased cylinder condensation. Saturated steam of any given pressure contains just sufficient

heat to maintain its state as steam at that pressure, and when the smallest amount of this heat is lost, as either by work done by it on the piston or simply by contact with the cylinder walls of lower temperature, a part of the steam must of necessity be condensed and appear as moisture on the cylinder surfaces.

6. The condensation caused by the cooling action of the cylinder walls is that in excess of the moisture shown by the steam tables, to be in the steam after adiabatic expansion.

7. For example: Dry saturated steam of 205 pounds (gage) pressure without addition of heat from any outside source such as a leaky valve or a steam jacket, and without giving up any heat, as heat, to any outside source, such as through unjacketed cylinder walls or a leaky piston, would be expanding adiabatically, that is, would be doing against the piston the maximum amount of work of which such steam is capable, by itself alone, between the set limits of pressure—and even then there would be approximately fifteen (15) per cent of moisture in the steam so expanded, so that the moisture, due to the cooling action of the cylinder walls, in that case, is that in excess of fifteen per cent.

8. The use of saturated steam appears to make comparatively great temperature changes in the cylinder walls during a stroke, due to greater conductivity of moist than of dry cylinder walls. Experiments with superheated steam, notably by Barrus (see Transactions, American Society of Mechanical Engineers, Vol. 29, 1907), appear to show that as the amount of superheat is increased, the range of temperature in the cylinder during a stroke of the piston is decreased until with sufficient superheat the changes in temperature cease entirely, and Barrus also stated in conclusion that, "A comparatively small portion of the drop in temperature was therefore due to the radiation losses and a large portion to the conversion of heat into work."

9. If the superheat is just sufficient to keep the steam above the saturation temperature up to the point of cut-off, the steam will act as saturated steam during expansion and there will be no possibility of superheat being lost in the exhaust steam. Whether or not the loss of heat due to superheat in the exhaust is a serious matter, it is true that the advocates of highly superheated steam

(180 degrees and upward) do not admit that there is any loss due to a moderate degree of superheat in the exhaust, because it is much more than offset by the less amount of heat exhausted per stroke, on account of the less amount of steam used per stroke, or the less amount of heat admitted to the cylinder per stroke at a given cut-off.

Application of Baldwin Superheater to H6b Locomotive.

10. The Baldwin Locomotive Works originated a system of smokebox superheating, which involved the use of low boiler pressure, and in March, 1909, locomotive No. 2846, a consolidation of the H6b class, then about four years old, was turned over to them and a smokebox superheater installed.

11. The boiler pressure adopted was 160 pounds instead of the usual pressure for this locomotive of 205 pounds To obtain the original drawbar pull it was necessary to enlarge the cylinders and new cylinders having a diameter of 25 inches instead of the original diameter of 22 inches, were made for this locomotive. The stroke was not changed but remained 28 inches. No other changes were made in the locomotive except those that has been noted.

The Superheater.

12. The superheater is wholly in the smokebox, as shown in Fig. 1 and receives heat from the gases issuing from the tubes. This heat would otherwise be discharged from the stack and lost.

13. Each side of the superheater is independent of the other and is in fact an enlargement and division of the branch pipe to the cylinder. The superheater is made up of 336, one and one-quarter inch tubes. Each tube is about 40 inches long and is expanded into a cast-steel header at each end. The outside heating surface of the tubes, without the headers, is 389 square feet for both sides.

14. The tubes of the superheater are divided into groups and the passages in the headers are so arranged that on each side

the steam passes through five banks of tubes in series. The steam thus passes through a length of pipe in the smokebox of about $17\frac{1}{2}$ feet. The temperature of the smokebox gases in this class of locomotive is normally from 500 to 700 degrees Fahrenheit without the superheater.

15. At a pressure of 160 pounds by gage, the saturation temperature of steam is 370 degrees Fahrenheit, and with a smokebox temperature of 600 degrees, but a moderate superheat is possible. The highest superheat obtained in the tests was 55.9 degrees Fahrenheit.

16. To measure the steam temperature, in obtaining the amount of superheat, mercury thermometers were used as shown in Fig. 2. These were placed in thermometer wells in each steam pipe. On account of the length of the mercury column above the well, a correction was made for each temperature reading.

17. No special determination of the amount of moisture in the saturated steam, entering the superheater, was made for this locomotive, but from a large number of tests with a throttling calorimeter, on this and other classes of locomotive, it has been found that the steam contains about 1.67 per cent. of moisture, without much variation for different rates of evaporation. A correction of the above amount has been made for the quality of the saturated steam.

Coal Analysis.

18. For all of the tests the coal was "run of mine" coal from Jamison No. 3 Colliery of the Jamison Coal and Coke Company. The proximate analysis of an average sample of this coal shows the following:

Fixed carbon, per cent	57.25
Volatile matter, per cent	31.95
Moisture, per cent	0.82
Ash, per cent	9.98
Total	100.00
Sulphur, separately determined, per cent	1.79
B. t. u. per lb. of coal, dry	14,014

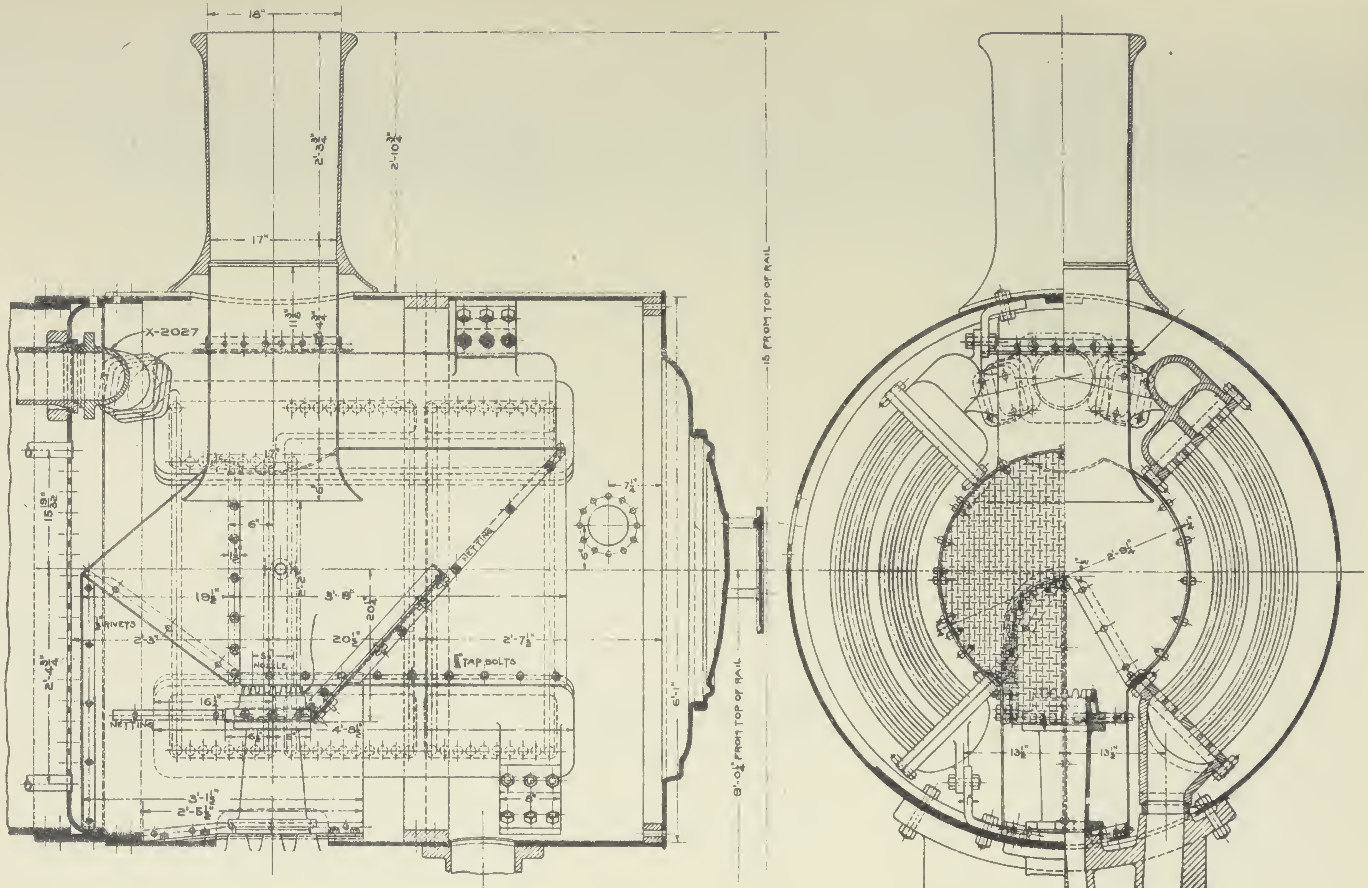
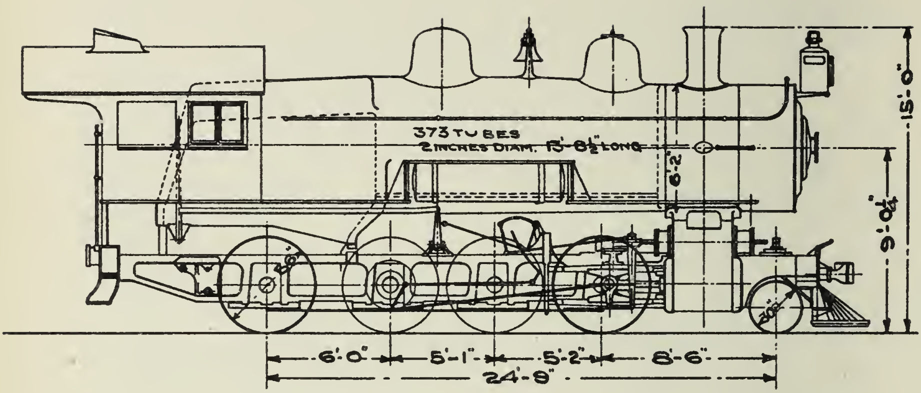


Fig. 1.

BALDWIN SMOKEBOX SUPERHEATER.

Cross section and end view of smokebox showing superheater in place. Class H6b locomotive.



Outline of H6b locomotive with smokebox superheater and 25-inch cylinders.

19. General Dimensions of Locomotive.

Total weight (normal weight of H6b class), pounds	202000
Weight on drivers (normal weight of H6b class), pounds	179000
Cylinders (simple), inches	25 x 28
Diameter of drivers, inches	56
Firebox heating surface, square feet	166.1
Heating surface in tubes (water side), square feet	2673.7
Heating surface of superheater, square feet	389.0
Total heating surface (based on water side of tubes), square feet (not including superheater)	2839.7
Total heating surface (based on fire side of tubes), square feet (not including superheater)	2505.3
Grate area, square feet	48.7
Boiler pressure, pounds	160
Valves	12 in. Piston
Valve motion	Walschaerts
Firebox, type	Wide, Belpaire
Number of tubes	373
Outside diameter of tubes, inches	2
Length of tubes, inches	164.3

The Tests.

20. The tests were made at three speeds, 80,100 and 120 revolutions per minute, 13 to 20 miles per hour.

21. After making some preliminary tests at low speeds a test was begun at 100 revolutions, 16.5 miles per hour and 50 per cent. cut-off, but the locomotive would not steam. The draft appeared to be insufficient and the smokebox filled with cinders.

22. The smokebox arrangement is shown in Fig. 3, the full lines indicated the parts originally in place. These consisted of

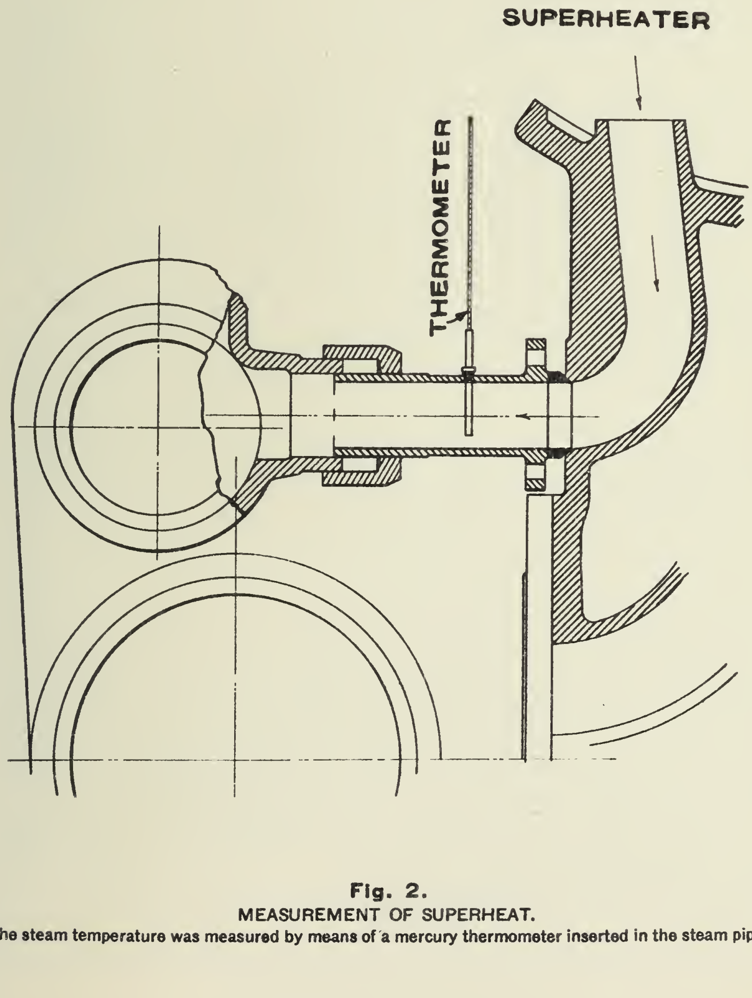


Fig. 2.
MEASUREMENT OF SUPERHEAT.
The steam temperature was measured by means of a mercury thermometer inserted in the steam pipe.

a cone-shaped piece extending forward from the tube sheet and connecting with a tube or cylinder. This cylinder had perforated sides and a section was omitted at the bottom. The gases passed in at the perforated part and at the part "A," the gases finding a short passage to the stack.

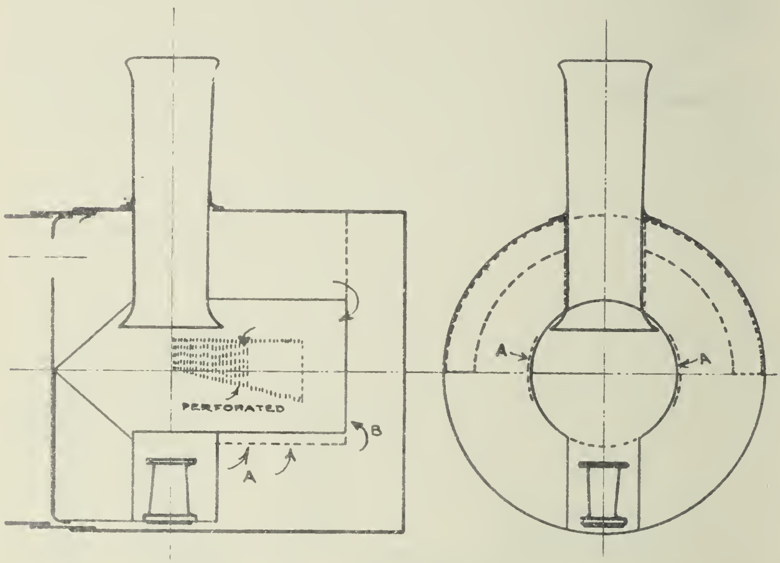


Fig. 3.
SMOKEBOX DEFLECTORS.
A cylindrical tube with a conical end is located on the center line of the smokebox. This part was reconstructed so that the gases would enter at the open end, B, instead of taking the short passage at A. The parts shown by broken lines were added during the tests.

23. To improve the draft by causing the gases to sweep out the cinders in the front of the smokebox, the perforations in the sides of the deflector were closed and the bottom of the cylinder of the deflector completed, so that the gases, instead of passing up at "A," were forced to enter the end of the deflector at "B." A deflector plate was also added at the top and sides of the smokebox. After these changes, the test tried before was easily made with a good steam pressure.

24. A test was later made at 120 revolutions, 20 miles per hour, and 50 per cent. cut-off, but showing a total evaporation less than that of the regular H6b class.

25. It was observed that, at any speed and cut-off, this locomotive with a 25-inch cylinder and 160 pounds pressure, has a drawbar pull very much less than an H6b locomotive with a 22-inch cylinder and 205 pounds pressure.

26. This is shown by the following table:

Comparison of Drawbar Pulls at Approximately Equal Cut-off.

Test No.	Locomotive No.	Steam	Speed in r.p.m.	Speed in m.p.h.	Cut-off in Per Cent.	i.h.p.	d.h.p.	Drawbar Pull Pound
1301	2846	Superheated	80	13	29.5	648.2	551	15495
1200.271	2860	Saturated	80	13	31.4	817.6	701	20234
1302	2846	Superheated	80	13	36.6	792.8	698.7	19648
1200.272	2860	Saturated	80	13	38.9	963.5	850.2	24256
1303	2846	Superheated	100	16	43.6	1046.2	908.7	20443
1200.274	2860	Saturated	100	16	45.7	1248.9	1111.8	25659

The superheater locomotive has a slightly shorter cut-off in these tests, but this is not nearly sufficient to account for the lower pull. This is evident from Fig. 4, where the mean effective pressure is shown for the cut-offs used.

27. We find from this diagram that at 80 revolutions per minute with saturated steam and a cut-off of 30 per cent., the saturated steam locomotive has a mean effective pressure of 90 pounds, while the superheated steam locomotive under the same conditions has a mean effective pressure of 76 pounds. Similar conditions are shown for the speeds at 100 and 120 revolutions. There is a drop in pressure as the steam passes through the superheater, and this accounts for a low drawbar pull, where the locomotive is using large quantities of steam. This however, does not account for the low mean effective pressure at low speeds. The only apparent reason for this is in the use of the same size of valves and steam ports in both cases, and the low superheat used with the larger cylinders.

Superheater Tests with a Boiler Pressure of 160 Pounds.

28. Tables I and II show the results of the tests at 160 pounds boiler pressure, or the pressure for which this superheater installation was designed.

29. Table I shows tests with the superheater in action, Table II with the superheater removed, but in both cases with the 25-inch cylinders. The superheat obtained was low, being only from 25 to 56 degrees. When evaporating 30000 pounds of water and this was about the limit for the locomotive, the drop in steam pressure from the boiler to the cylinders was 7.2 pounds.

30. In Figs. 5 to 9 which show the results of these tests with 160 pounds pressure, there is a saving shown in both water and coal, the saving in water averages about 8 per cent., and in coal about 15 per cent., the drawbar pull, however, is low.

31. The locomotive with a superheater and 25-inch cylinders is in this case compared with the same locomotive without superheater, but also with 25-inch cylinders. This is not a fair comparison, because this class of locomotive, under normal conditions, has a 22-inch cylinder. The 25-inch cylinder, operated on superheated steam, shows a high water rate, due no doubt to cylinder condensation.

32. A much better comparison of the 160 pounds pressure tests is found in Figs. 24 to 27, where the superheater locomotive is compared with another H6b locomotive having 22-inch cylinders, in this case no advantage is shown for the superheater locomotive.

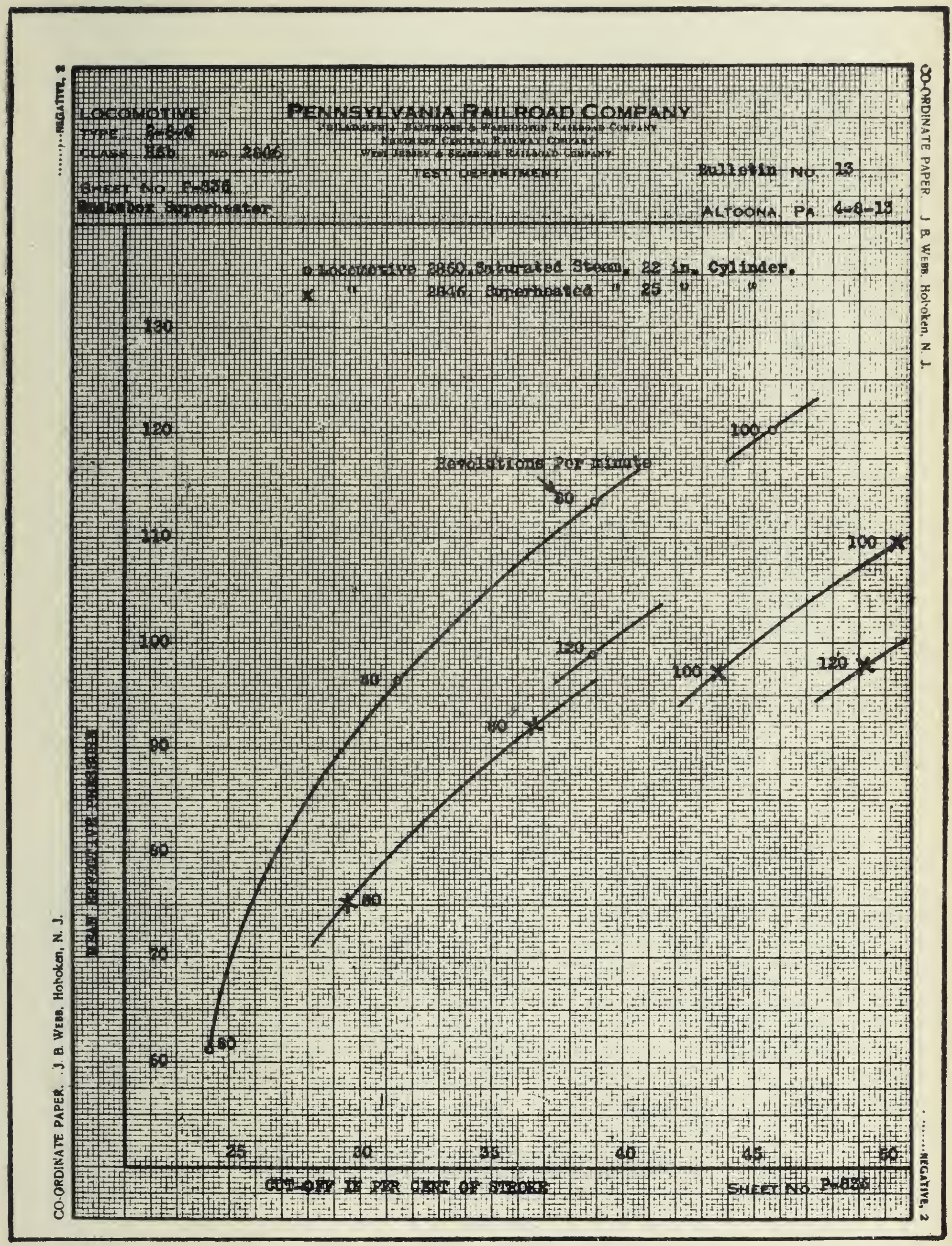


Fig. 4.

MEAN EFFECTIVE PRESSURE.

The pressure for the 25-inch cylinder has been multiplied by 1.29, the ratio of cylinder diameters of the two locomotives.

M. P. 394 A—Sixth Sheet
8 × 10½

11-9-1

PENNSYLVANIA RAILROAD COMPANY

Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company

TEST DEPARTMENT

AVERAGE RESULTS OF LOCOMOTIVE TESTS

LOCOMOTIVE:
TYPE 2-8-0
CLASS H6b
NUMBER 2846

Bulletin No. 13
FUEL: Jamison Coal

SUBJECT: Smokebox Superheater

ALTOONA, PA., 3-31-1909

TEST NUMBER	RUNNING CONDITIONS: Test Designation	Duration of Test, Hours	Miles per Hour	Throttle Opening, Full or Partial	Actual Cut-off Per Cent., H. P. Cylinders	Temp. of Smoke-box Degrees F	BOILER PERFORMANCE: Pressure in Boiler, Lbs. per Sq. Inch	Draft in Smoke Box, Inches of Water	Draft in Ash Pan, Inches of Water	Calorific Value of Dry Fuel, B. T. U. per Lb.	Cinders Collected in Smoke Box, Pounds per Hour
	R. P. M. Cut-off Throttle	196	199	203	268 to 271		217	222	225	248	238
1301	80-30-F	2	13.34	Full	29.5	475	159.9	1.5	.1	13293	77
1302	80-40-F	2	13.34	"	36.6	500	160.6	2.1	.1	13293	138
1303	100-45-F	2	16.67	"	43.6	570	159.0	4.0	.1	13293	248
1304	100-50-F		Smokebox	Filled	With Cinders						
1305	100-50-F	2	16.67	Full	50.4	548	162.4	6.9	.3	13293	109
1306	120-50-F	1.5	20.00	"	49.2	600	157.6	7.8	.3	13293	155

TEST NUMBER	BOILER PERFORMANCE: Dry Fuel Fired per Hour, Pounds	Dry Fuel per Hour, Pounds per Sq. Ft. of Grate	Water Delivered to Boiler, Pounds per Hour	Equivalent Evaporation from and at 212° F., Pounds: Per Hour	Per Hour per Sq. Ft. of Fire Heating Sur.	Per Pound of Dry Fuel	Boiler Horse Power (34½ U. of E.)	Efficiency of Boiler, Based on Fuel	Kind of Super-heater	ENGINE PERFORMANCE: Pressure in Branch Pipe, Pounds per Sq. In.	Superheat in Branch Pipe Degrees F.
	338	339	340	344	345	347	349	350		220	230
1301	2071	42.53	16166	19603	7.82	9.47	568.2	68.80	Baldwin	156.6	25.0
1302	2683	55.09	19831	24077	9.61	8.97	697.9	65.17	"	156.6	32.8
1303	3683	75.63	25860	31372	12.52	8.52	909.3	61.91	"	153.8	44.3
1304											
1305	4584	94.13	30115	36558	14.59	7.98	1059.7	57.98	"	155.1	55.9
1306	5543	113.86	32722	39690	15.84	7.16	1150.4	52.02	"	154.0	54.7

TEST NUMBER	ENGINE PERFORMANCE: Dry Steam to Engines, Pounds per Hour	Indicated Horse Power	Dry Fuel per Indicated Horse Power Hour, Pounds	Dry Steam per Indicated Horse Power Hour, Pounds		LOCOMOTIVE PERFORMANCE: Drawbar Pull, Pounds	Dynamometer or Drawbar Horse Power	Dry Fuel per Dynamom. Horse Power Hour, Pounds	Dry Steam per Dynamom. Horse Power Hour, Pounds	Machine Efficiency of Locomotive, Per Cent.	Thermal Efficiency of Locomotive, per Cent., (Based on Fuel)	Temp. of Steam in Branch Pipe Degrees F
	214	379	380	381		265	363	384	385	398	399	
1301	15901	648.2	3.2	24.53		15495	551.0	3.76	28.86	85.0	5.09	393.7
1302	19561	792.8	3.4	24.67		19648	698.7	3.84	28.00	88.1	4.99	401.4
1303	25531	1046.2	3.5	24.40		20443	908.7	4.05	28.10	86.9	4.73	408.0
1304												
1305	29730	1179.0	3.9	25.22		23135	1028.4	4.46	28.91	87.2	4.29	423.7
1306	32307	1265.2	4.4	25.54		20184	1076.6	5.15	30.01	85.1	3.72	422.0

BOILER PRESSURE 160

Table I.

Superheater in use. Steam pressure 160 pounds. 25-inch cylinders.

M. P. 394 A—Sixth Sheet
5 x 10½

11-9-10

PENNSYLVANIA RAILROAD COMPANY

Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company

TEST DEPARTMENT

LOCOMOTIVE:
TYPE 2-8-0
CLASS H6b, 25 in. cylinders
NUMBER 2846

Bulletin No. 13
FUEL: Jamison Coal

AVERAGE RESULTS OF LOCOMOTIVE TESTS

SUBJECT: Smokebox Superheater, Trials With Saturated Steam — ALTOONA, PA., 4-8-1909

TEST NUMBER	RUNNING CONDITIONS: TEST DESIGNATION	Duration of Test, Hours	Miles per Hour	Throttle Opening, Full or Partial	Actual Cut-off Per Cent., H. P. Cylinders	Temp. of Smoke-box Degrees F	BOILER PERFORMANCE: Pressure in Boiler, Lbs. per Sq. Inch	Draft in Smoke Box, Inches of Water	Draft in Ash Pan, Inches of Water	Calorific Value of Dry Fuel, B. T. U. per Lb	Cinders Collected in Smoke Box, Pounds per Hour
	R. P. M. Cut-off Throttle	196	199	203	268 to 271		217	222	225	248	238
1317	80-30-F	2	13.34	Full	27.8	520	158.0	1.9	.1	13580	69
1318	80-40-F	2	13.34	"	35.6	545	160.5	2.5	.1	13580	116
1319	100-45-F	2	16.67	"	43.4	610	160.9		.2	13580	256
1320	120-50-F	1	20.00	"	50.3	700	147.6	4.7	.3	13580	658

TEST NUMBER	BOILER PERFORMANCE: Dry Fuel Fired per Hour, Pounds	Dry Fuel per Hour, Pounds per Sq. Ft. of Grate	Water Delivered to Boiler, Pounds per Hour	Equivalent Evaporation from and at 212° F., Pounds: Per Hour	Per Hour per Sq. Ft. of Fire Heating Sur.	Per Pound of Dry Fuel	Boiler Horse Power (34½ U. of E.)	Efficiency of Boiler, Based on Fuel		ENGINE PERFORMANCE: Pressure in Branch Pipe, Pounds per Sq. In.	Superheat in Branch Pipe Degrees F.
	338	339	340	344	345	347	349	350		220	230
1317	2334	47.93	17689	21398	8.54	9.17	620.2	65.22		156.2	
1318	3118	64.03	21725	26366	10.52	8.46	764.3	60.17		159.5	
1319	4572	93.88	28779	34828	13.90	7.62	1009.5	54.19			
1320	6687	137.31	33281	40230	16.06	6.02	1166.1	42.81			

TEST NUMBER	ENGINE PERFORMANCE: Dry Steam to Engines, Pounds per Hour	Indicated Horse Power	Dry Fuel per Indicated Horse Power Hour, Pounds	Dry Steam per Indicated Horse Power Hour, Pounds		LOCOMOTIVE PERFORMANCE: Drawbar Pull, Pounds	Dynamometer or Drawbar Horse Power	Dry Fuel per Dynamom. Horse Power Hour, Pounds	Dry Steam per Dynamom. Horse Power Hour, Pounds	Machine Efficiency of Locomotive, Per Cent.	Thermal Efficiency of Locomotive, per Cent., (Based on Fuel)	Temp. of Steam in Branch Pipe Degrees F
	214	379	380	381		285	383	384	385	398	399	
1317	17475	644.4	3.6	27.12		15238	541.9	4.31	32.25	84.1	4.35	367.1
1318	21394	812.2	3.8	26.34		19649	698.7	4.46	30.62	86.0	4.20	367.9
1319	28323	1074.6	4.3	26.36		20742	922.0	4.96	30.72	85.8	3.78	367.6
1320	32878	1156.0	5.8	28.39		18507	987.2	6.77	33.30	85.3	2.77	358.6

BOILER PRESSURE 160

Table II.

In these tests the superheater was removed and replaced by steam pipes. Steam pressure 160 pounds. 25-inch cylinders.

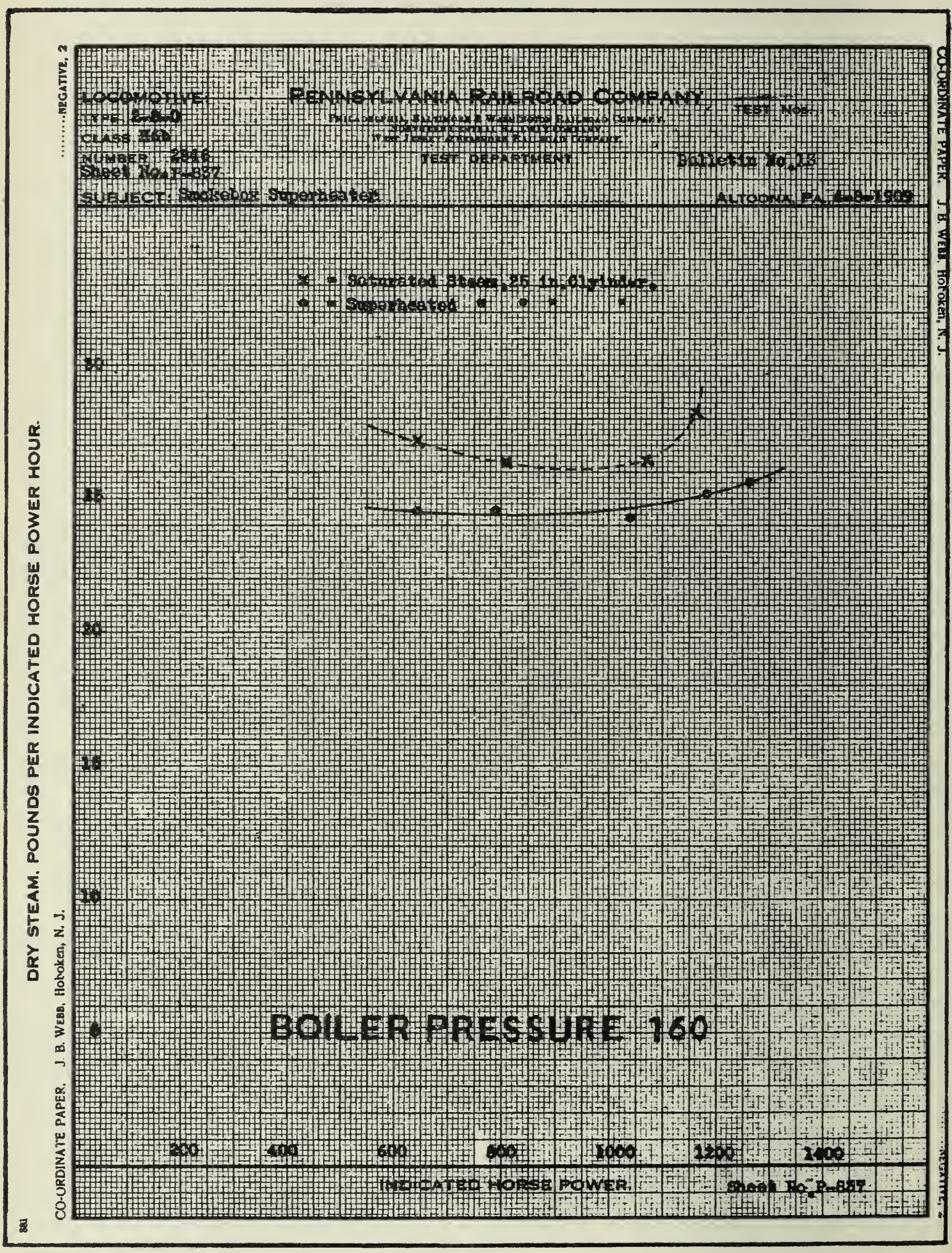


Fig. 5.

STEAM PER INDICATED HORSE-POWER.

The superheat ranges from 25 to 55 degrees, and there is an average saving in steam of 8 per cent.

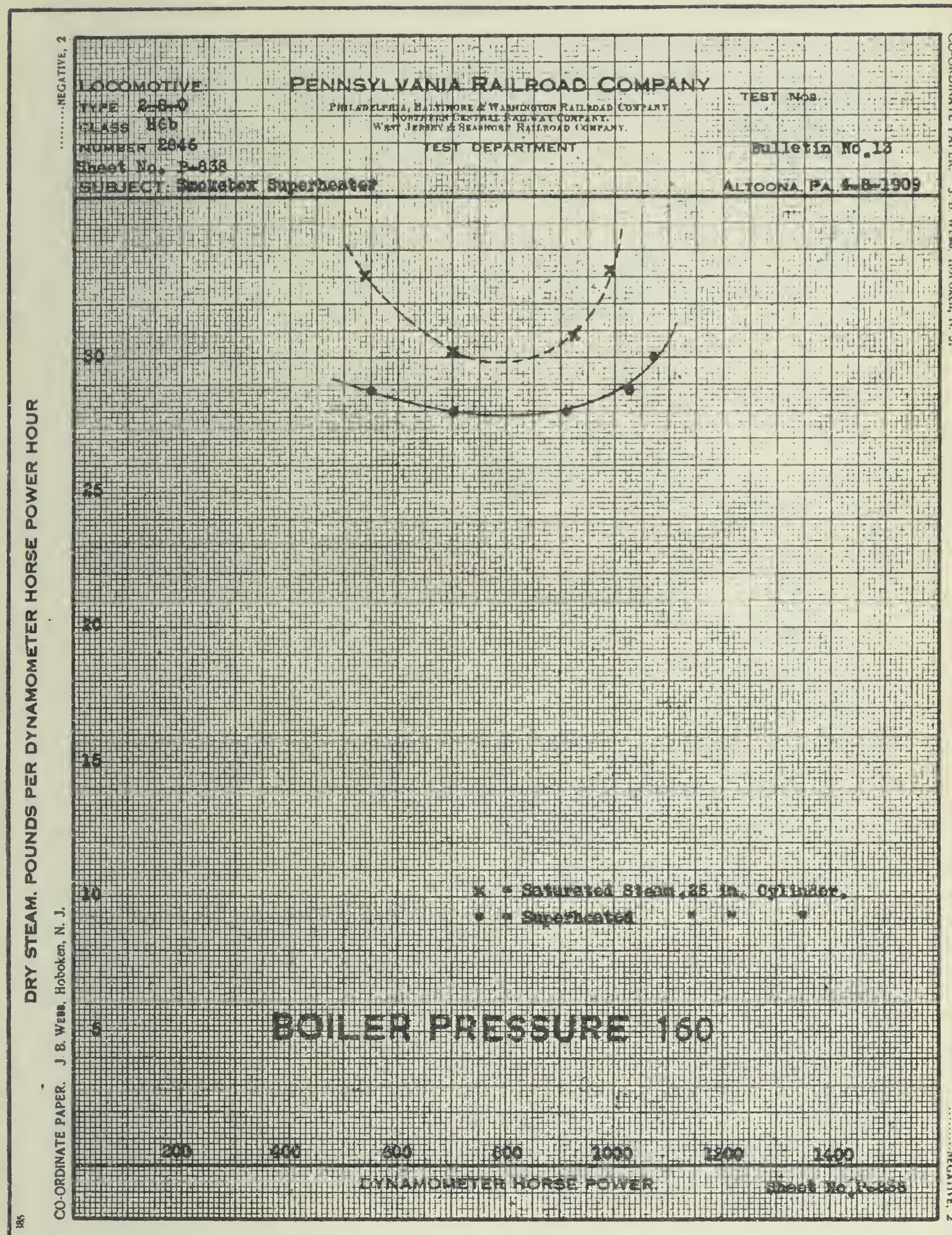


Fig. 6.
STEAM PER DYNAMOMETER HORSE-POWER.
Boiler pressure 160 pounds.

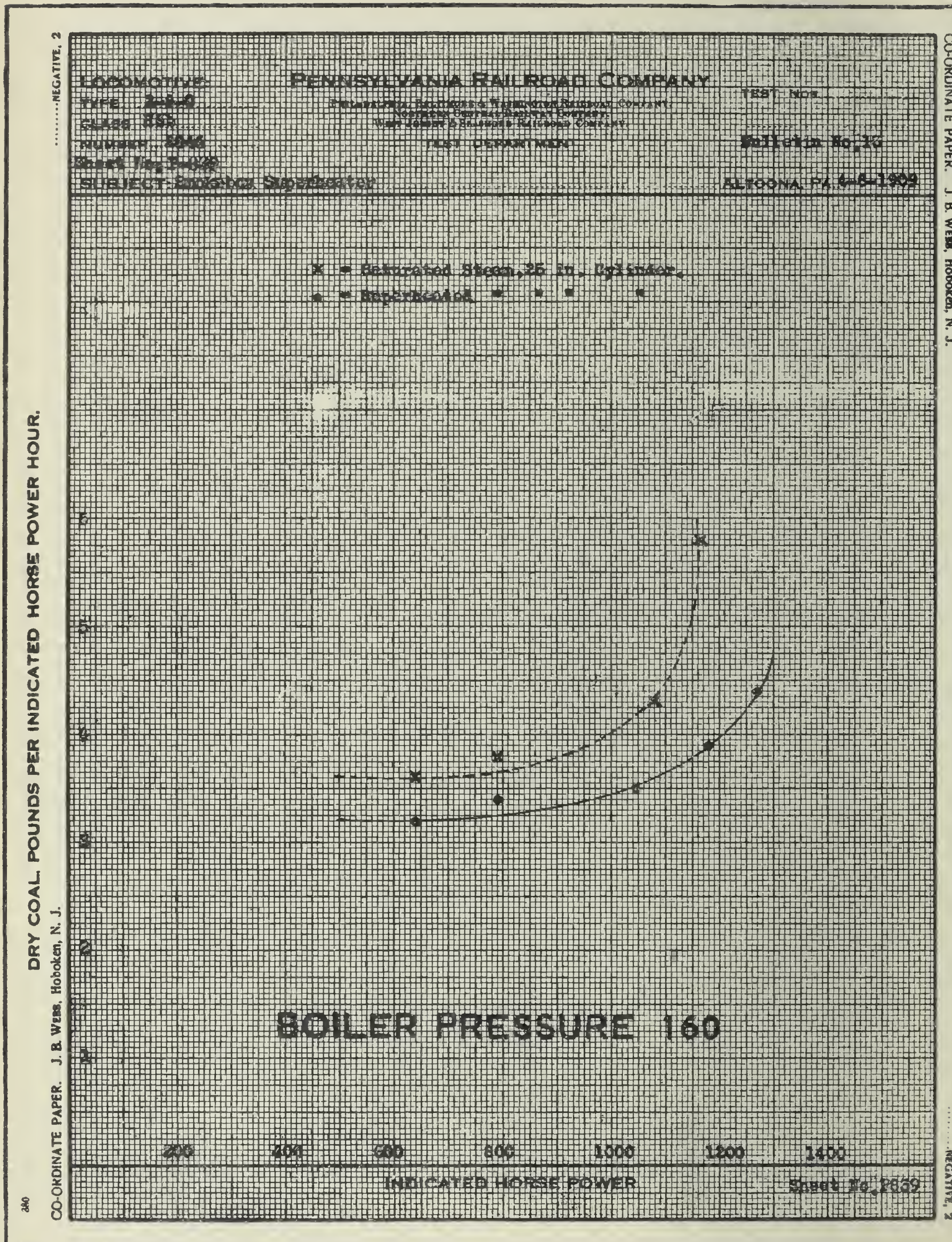


Fig. 7.
COAL PER INDICATED HORSE-POWER.
Boiler pressure 160 pounds.

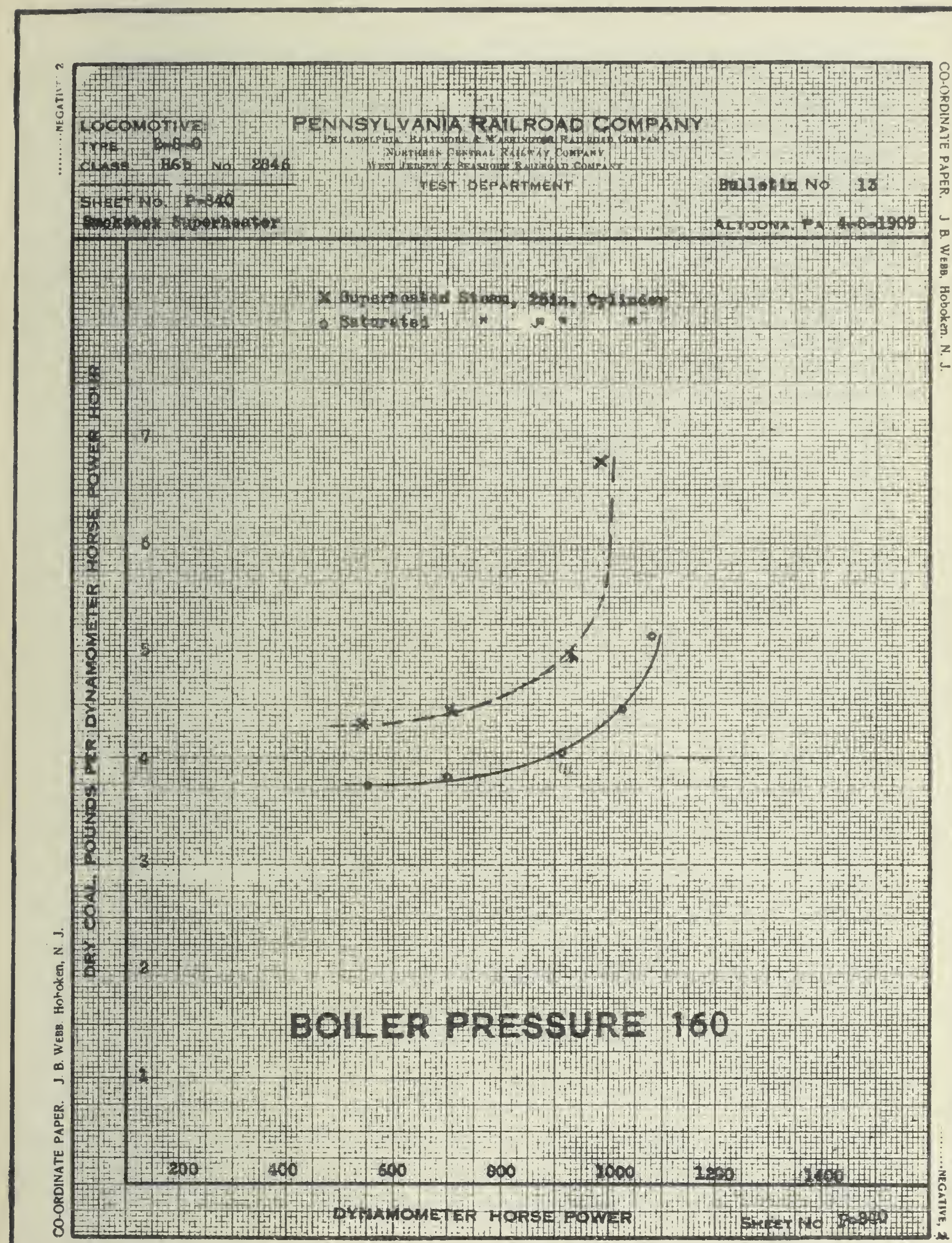


Fig. 8.

COAL PER DYNAMOMETER HORSE-POWER.

We find here a saving in coal of 15.8 per cent.

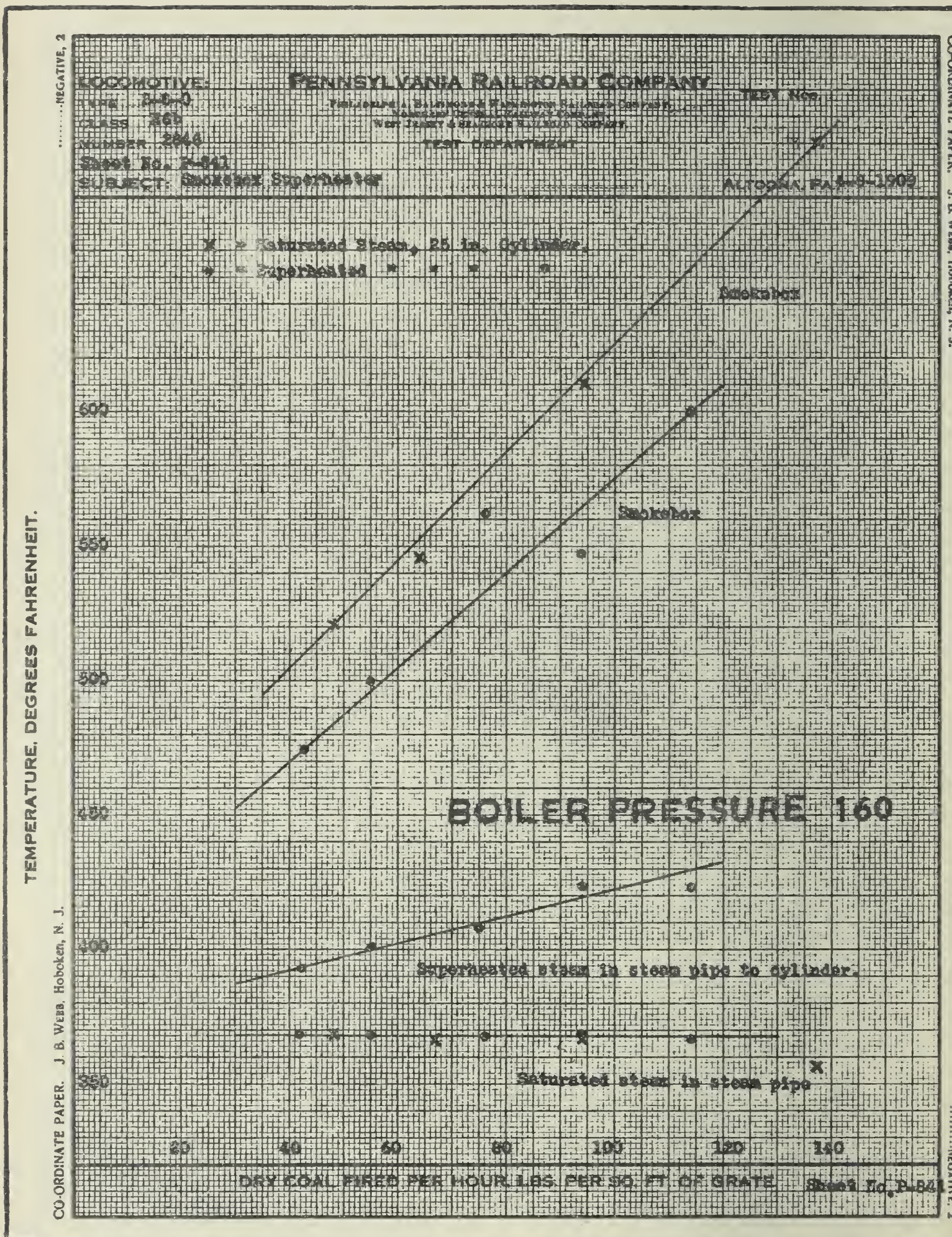


Fig. 9.

TEMPERATURES OF SMOKEBOX GASES AND STEAM.

With the superheater in use, the temperature of the gases is decreased and heat is recovered.

Superheater Tests at Increased Pressures.

33. The boiler pressure was then increased to 170 pounds and a second series of trials made at the same speeds and cut-offs as for the tests at 160 pounds pressure, and following these a series of tests at 180 pounds pressure was made. Even at 180 pounds pressure, the drawbar pulls of the two locomotives are not equal.

Superheater Locomotive Operated on Saturated Steam.

34. Because of the fact that the locomotive did not show results equal to those obtained with the H6b (saturated steam, 22-inch cylinders) either in drawbar pull or boiler power. It was decided to remove the superheater and substitute the usual steam pipes so that trials could be made with saturated steam. These trials were made at the former speeds and cut-offs and are comparable with the trials with superheat.

35. From these tests it is found that the superheater reduces the steam consumption about 6½ per cent. at pressures of 160 and 170 pounds, with conflicting results at 180 pounds pressure.

Comparative Trials with a Saturated Steam Locomotive.

36. After all of the trials of the superheater locomotive 2846 were completed, a series of trials was run with class H6b saturated steam locomotive 2860, repeating runs made with locomotive 2846 and using the same kind of coal. Saturated steam locomotive 2860 has 22-inch diameter cylinders and carries a boiler pressure of 205 pounds.

37. The results of these tests are given on Table VII, and they are plotted, in connection with the results of the tests on the superheater locomotive, in Figs. 23 to 27.

38. The ratio of the areas of cylinders of the two locomotives 2860 and 2846 is 1.29 while the ratio of the boiler pressures of 205 to 160 is 1.28. The 25-inch cylinders are thus large enough if they received the pressure expected, but this they do not have on account of the restriction of the steam passages of the superheater.

M. P. 394 A—Sixth Sheet
8 x 10½ 11-4-10

PENNSYLVANIA RAILROAD COMPANY

Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company

TEST DEPARTMENT

AVERAGE RESULTS OF LOCOMOTIVE TESTS

LOCOMOTIVE:
TYPE 2-8-0
CLASS H6b Superheater
NUMBER 2846

Bulletin No.13
FUEL: Jamison Coal

SUBJECT: Smokebox Superheater

ALTOONA, PA., 4-1-1909

TEST NUMBER	RUNNING CONDITIONS: TEST DESIGNATION	Duration of Test, Hours	Miles per Hour	Throttle Opening, Full or Partial	Actual Cut-off Per Cent., H. P. Cylinders	Temp. of Smoke-box Degrees F	BOILER PERFORMANCE: Pressure in Boiler, Lbs. per Sq. Inch	Draft in Smoke Box, Inches of Water	Draft in Ash Pan, Inches of Water	Calorific Value of Dry Fuel, B. T. U. per Lb.	Cinders Collected in Smoke Box, Pounds per Hour
	S. P. M. Cut-off Throttle	196	199	203	268 to 271		217	222	225	248	238
1307	80-30-F	2	13.34	Full	28.1	480	173.4	2.4	.1	13293	43
1308	80-40-F	2	13.34	"	36.5	530	173.8	3.5	.1	13293	64
1309	100-45-F	2	16.67	"	41.4	570	170.1	5.5	.2	14218	92
1310	100-50-F	2	16.67	"	48.4	610	170.2	7.1	.3	14218	116
1311	120-50-F	1	20.00	"	48.2	620	167.7	8.7	.3	14218	260

TEST NUMBER	BOILER PERFORMANCE: Dry Fuel Fired per Hour, Pounds	Dry Fuel per Hour. Pounds per Sq. Ft. of Grate	Water Delivered to Boiler, Pounds per Hour	EQUIVALENT EVAPORATION FROM AND AT 212° F., POUNDS: Per Hour	Per Hour per Sq. Ft. of Fire Heating Sur.	Per Pound of Dry Fuel	Boiler Horse Power (34½ U. of E.)	Efficiency of Boiler, Based on Fuel	Kind of Super-heater	ENGINE PERFORMANCE: Pressure in Branch Pipe, Pounds per Sq In.	Superheat in Branch Pipe Degrees F.
	338	339	340	344	345	347	349	350		220	230
1307	2201	45.20	17857	21723	8.67	9.87	629.7	71.71	Baldwin	173.1	32.5
1308	2875	59.03	21292	25895	10.34	9.01	750.6	65.46	"	170.6	34.1
1309	4095	84.09	27429	33359	13.32	8.15	966.9	55.36	"	164.6	45.9
1310	5184	106.45	30576	37184	14.84	7.17	1077.8	48.70	"	163.7	44.3
1311	6918	142.05	33528	40760	16.27	5.89	1181.4	40.01	"	160.2	43.6

TEST NUMBER	ENGINE PERFORMANCE: Dry Steam to Engines, Pounds per Hour	Indicated Horse Power	Dry Fuel per Indicated Horse Power Hour, Pounds	Dry Steam per Indicated Horse Power Hour, Pounds		LOCOMOTIVE PERFORMANCE: Drawbar Pull, Pounds	Dynamometer or Drawbar Horse Power	Dry Fuel per Dynamom. Horse Power Hour, Pounds	Dry Steam per Dynamom. Horse Power Hour, Pounds	Machine Efficiency of Locomotive, Per Cent.	Thermal Efficiency of Locomotive, per Cent., (Based on Fuel)	Temp. of Steam in Branch Pipe Degrees F
	214	379	380	381		285	383	384	385	398	399	
1307	17541	732.8	3.0	23.94		17288	614.8	3.58	28.53	83.9	5.35	408.6
1308	21034	885.3	3.2	23.76		21328	758.4	3.79	27.73	85.7	5.05	409.6
1309	27097	1130.0	3.6	23.98		21825	970.1	4.22	27.93	85.8	4.24	418.2
1310	30201	1242.6	4.2	24.30		24624	1067.9	4.85	28.28	85.9	3.67	416.3
1311	33122	1298.6	5.3	25.51		21018	1121.1	6.17	29.54	86.3	2.90	414.0

BOILER PRESSURE 170

Table III.

Superheater in use. Steam pressure 170 pounds.

M. P. 394 A—Sixth Sheet
8 x 10½

11-4-10

PENNSYLVANIA RAILROAD COMPANY

Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company

TEST DEPARTMENT

AVERAGE RESULTS OF LOCOMOTIVE TESTS

LOCOMOTIVE:
TYPE 2-8-0
CLASS H6b, 25 in.Cylinders
NUMBER 2846

Bulletin No.13
FUEL: Jamison Coal

SUBJECT: Smokebox Superheater, Trials With Saturated Steam ALTOONA, PA., 4-14-1909

TEST NUMBER	RUNNING CONDITIONS						BOILER PERFORMANCE				
	TEST DESIGNATION	Duration of Test, Hours	Miles per Hour	Throttle Opening, Full or Partial	Actual Cut-off Per Cent., H. P. Cylinders	Temp.of Smoke-box Degrees F	Pressure in Boiler, Lbs. per Sq. Inch	Draft in Smoke Box, Inches of Water	Draft in Ash Pan, Inches of Water	Calorific Value of Dry Fuel, B. T. U. per Lb.	Cinders Collected in Smoke Box, Pounds per Hour
	R. P. M. Cut-off Throttle	196	199	203	268 to 271		217	222	225	248	238
1321	80-30-F	2	13.34	Full	28.7	520	169.9	1.9	.1	13580	61
1322	80-40-F	2	13.34	"	36.1	550	170.9	2.7	.2	13580	111
1323	100-45-F	2	16.67	"	43.5	645	169.8	4.6	.3	13697	296
1324	120-45-F	1.5	20.00	"	43.9	660	152.4	4.3	.2	13697	

TEST NUMBER	BOILER PERFORMANCE									ENGINE PERFORMANCE	
				EQUIVALENT EVAPORATION FROM AND AT 212° F., POUNDS							
	Dry Fuel Fired per Hour, Pounds	Dry Fuel per Hour, Pounds per Sq. Ft. of Grate	Water Delivered to Boiler, Pounds per Hour	Per Hour	Per Hour per Sq. Ft. of Fire Heating Sur.	Per Pound of Dry Fuel	Boiler Horse Power (34½ U. of E.)	Efficiency of Boiler, Based on Fuel		Pressure in Branch Pipe, Pounds per Sq. In.	Superheat in Branch Pipe Degrees F.
	338	339	340	344	345	347	349	350		220	230
1321	2520	51.75	19350	23413	9.35	9.29	678.6	66.07		170.1	
1322	3175	65.20	23093	28009	11.18	8.82	811.9	62.73		170.3	
1323	4817	98.91	30383	36831	14.70	7.65	1067.6	53.94		166.7	
1324	4841	99.41	29359	35489	14.17	7.33	1028.7	51.69		150.0	

TEST NUMBER	ENGINE PERFORMANCE					LOCOMOTIVE PERFORMANCE						
	Dry Steam to Engines, Pounds per Hour	Indicated Horse Power	Dry Fuel per Indicated Horse Power Hour, Pounds	Dry Steam per Indicated Horse Power Hour, Pounds		Drawbar Pull, Pounds	Dynamometer or Drawbar Horse Power	Dry Fuel per Dynamom. Horse Power Hour, Pounds	Dry Steam per Dynamom. Horse Power Hour, Pounds	Machine Efficiency of Locomotive, Per Cent.	Thermal Efficiency of Locomotive, per Cent., (Based on Fuel)	Temp.of Steam in Branch Pipe Degrees F
	214	379	380	381		265	383	384	385	398	399	
1321	18970	709.9	3.5	26.72		16663	592.5	4.25	32.02	83.5	4.41	372.9
1322	22729	885.2	3.6	25.68		21224	754.7	4.21	30.12	85.3	4.45	372.1
1323	30004	1157.1	4.2	25.93		22243	988.7	4.87	30.35	85.4	3.82	372.1
1324	29004	1112.1	4.4	26.08		17427	929.6	5.21	31.20	83.6	3.59	363.9

BOILER PRESSURE 170

Table IV.
Tests with superheater removed. Steam pressure 170 pounds.

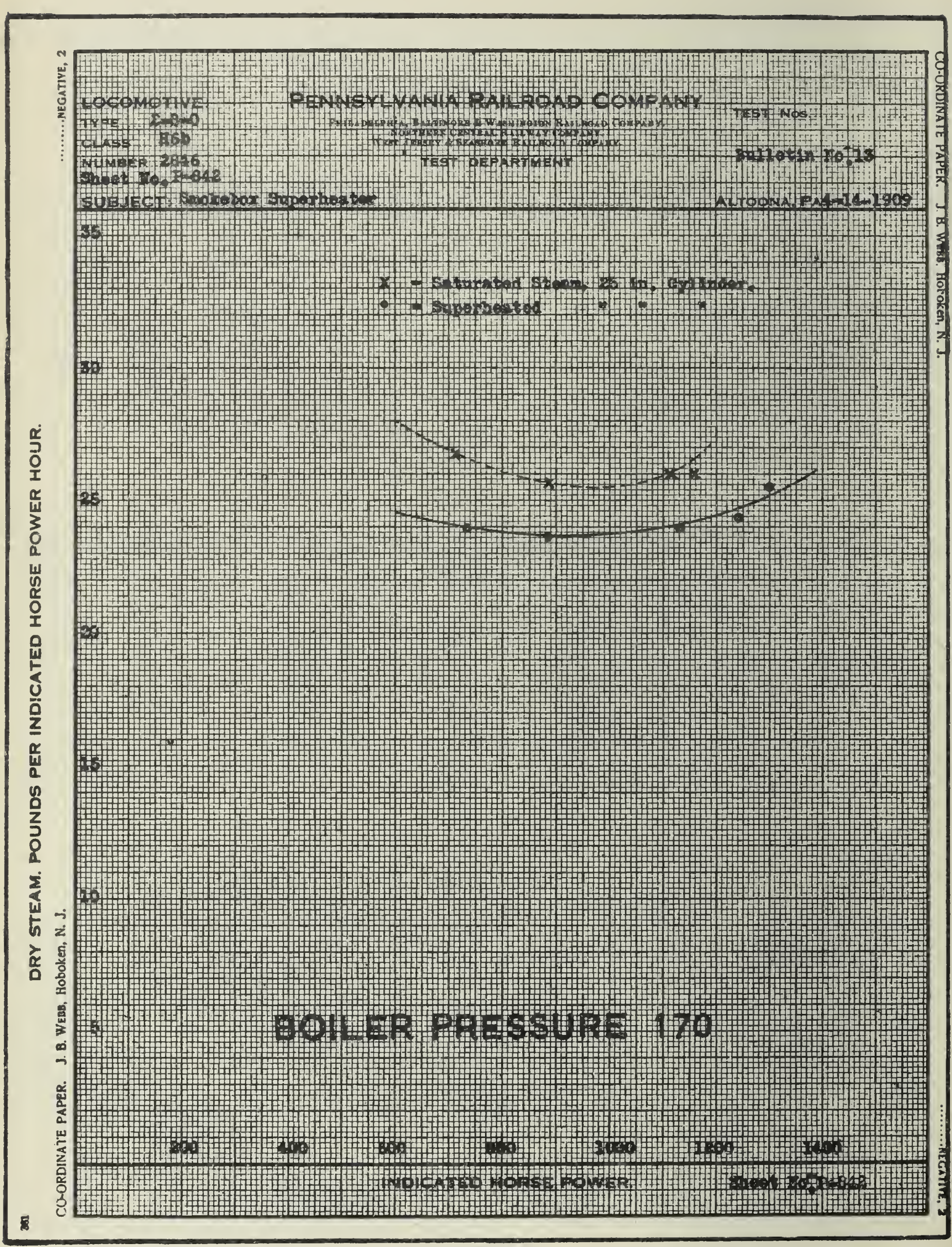


Fig. 10.

STEAM PER INDICATED HORSE-POWER.

Boiler pressure 170 pounds.

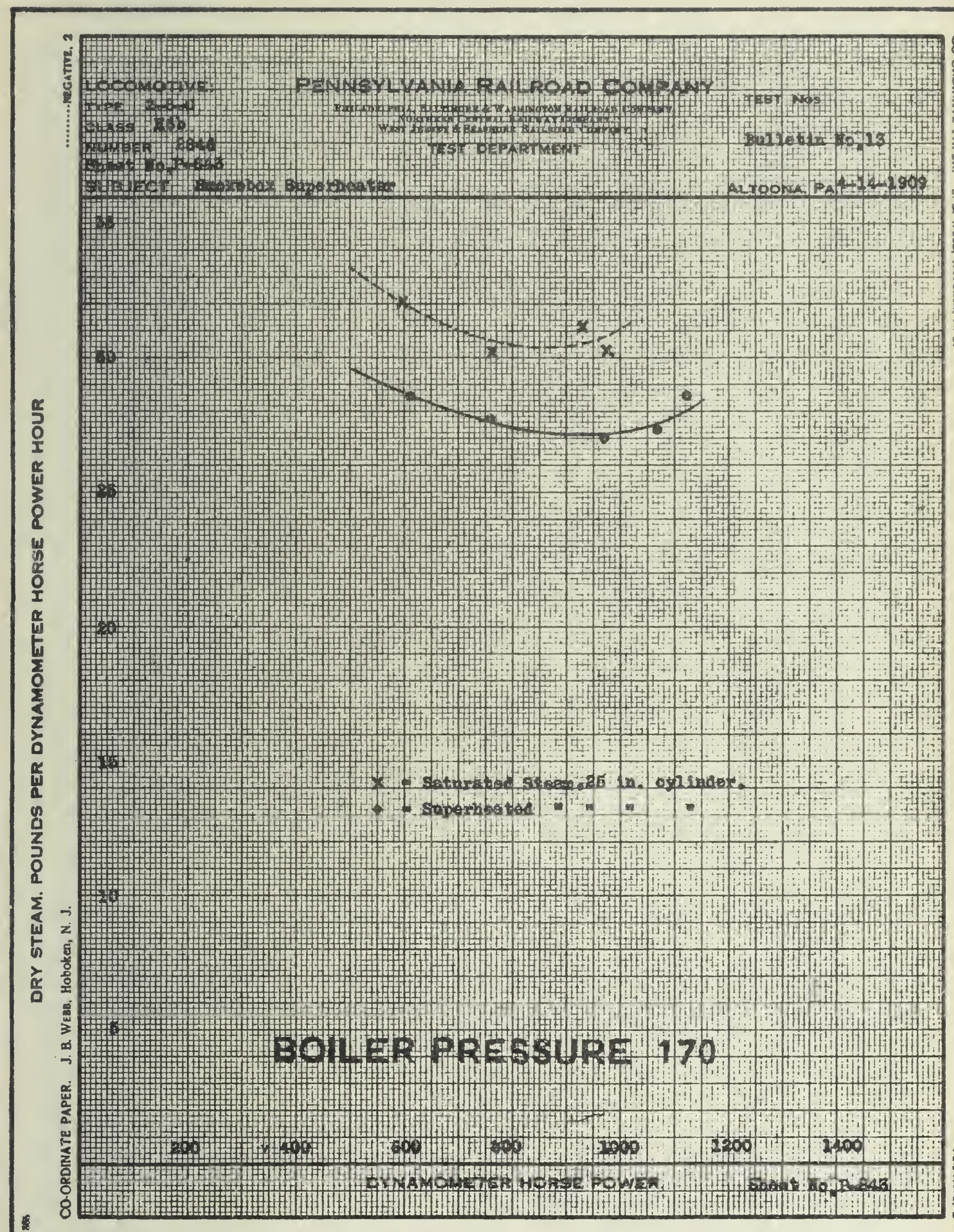


Fig. 11.
STEAM PER DYNAMOMETER HORSE-POWER.
Boiler pressure 170 pounds.

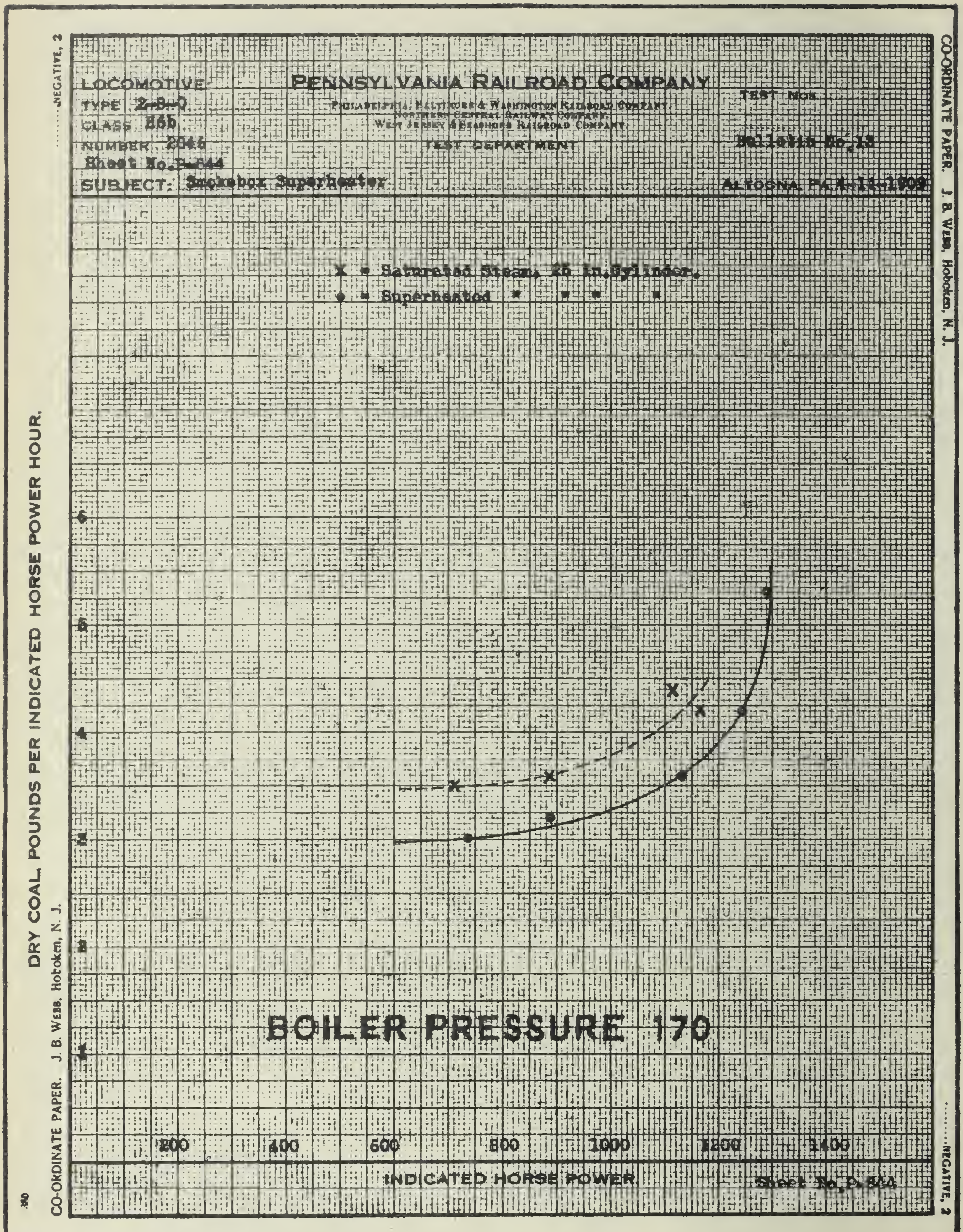


Fig. 12.

COAL PER INDICATED HORSE-POWER.

Boiler pressure 170 pounds.

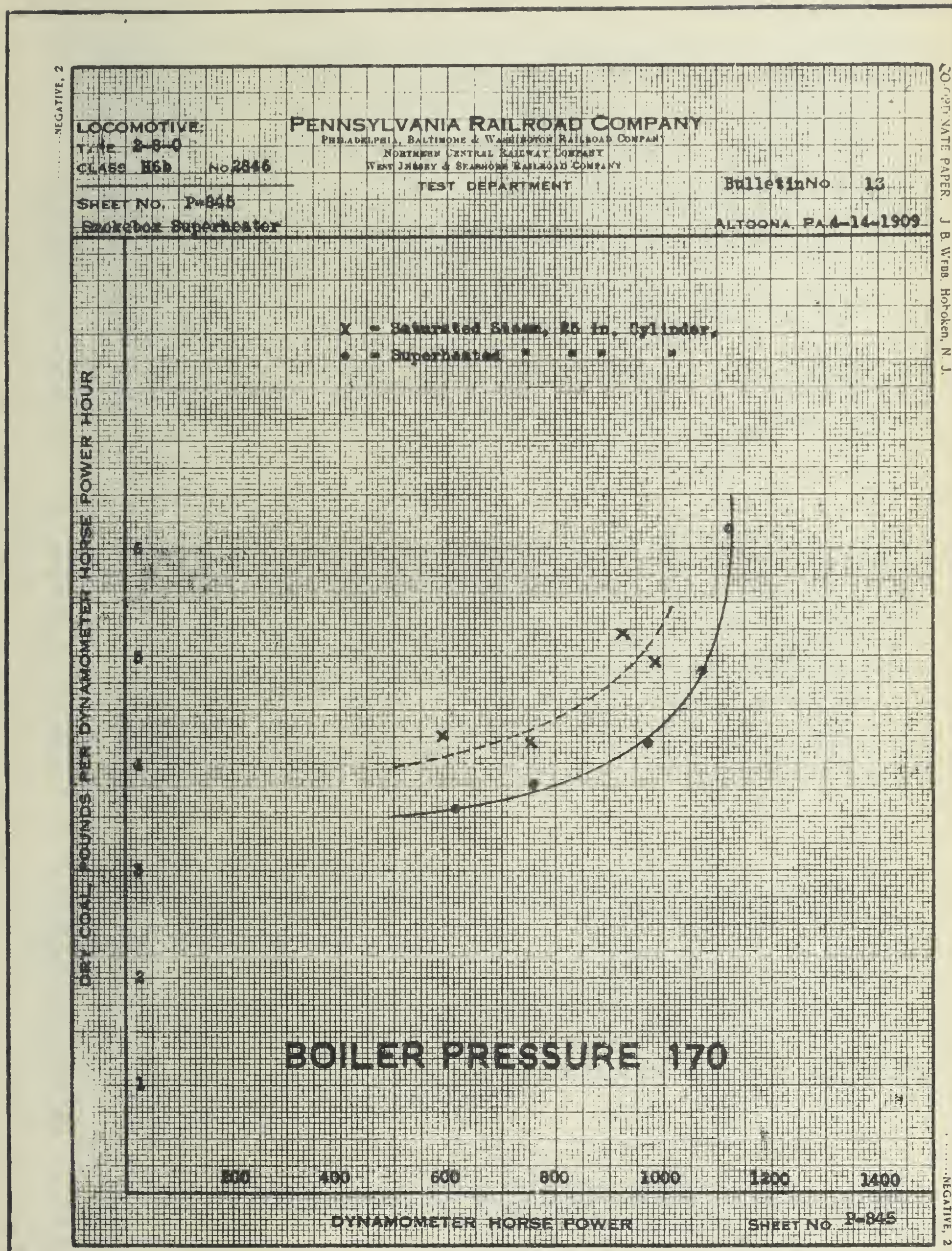


Fig. 13.
COAL PER DYNAMOMETER HORSE-POWER.
Boiler pressure 170 pounds.

M. P. 394 A—Sixth Sheet
8 x 10½

11-9-10

PENNSYLVANIA RAILROAD COMPANY

Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company

TEST DEPARTMENT

Bulletin No. 13

LOCOMOTIVE:
TYPE 2-8-0
CLASS H6b
NUMBER 2846

FUEL: Jamison Coal

AVERAGE RESULTS OF LOCOMOTIVE TESTS

SUBJECT: Smokebox Superheater

ALTOONA, PA., 4-3-1909

TEST NUMBER	RUNNING CONDITIONS: TEST DESIGNATION	Duration of Test, Hours	Miles per Hour	Throttle Opening, Full or Partial	Actual Cut-off Per Cent., H. P. Cylinders	Temp. of Smoke-box Degrees F	BOILER PERFORMANCE: Pressure in Boiler, Lbs. per Sq. Inch	Draft in Smoke Box, Inches of Water	Draft in Ash Pan, Inches of Water	Calorific Value of Dry Fuel, B. T. U. per Lb.	Cinders Collected in Smoke Box, Pounds per Hour
	R. P. M. Cut-off Throttle	196	199	203	268 to 271		217	222	225	248	238
1312	80-30-F	2	13.34	Full	30.7	500	181.5	3.1	.1	14218	56
1316	80-30-F	2	13.34	"	29.8	510	182.9	2.5	.1	13580	51
1313	80-40-F	2	13.34	"	36.4	545	182.3	4.0	.2	14218	85
1314	100-45-F	1.5	16.67	"	43.5	575	180.9	5.0	.2	14218	192
1315	120-50-F	1	20.00	"	49.3	625	163.3	6.8	.3	14218	280

TEST NUMBER	BOILER PERFORMANCE: Dry Fuel Fired per Hour, Pounds	Dry Fuel per Hour. Pounds per Sq. Ft. of Grate	Water Delivered to Boiler, Pounds per Hour	EQUIVALENT EVAPORATION FROM AND AT 212° F., POUNDS: Per Hour	Per Hour per Sq. Ft. of Fire Heating Sur.	Per Pound of Dry Fuel	Boiler Horse Power (34½ U. of E.)	Efficiency of Boiler. Based on Fuel	Kind of Super-heater	ENGINE PERFORMANCE: Pressure in Branch Pipe, Pounds per Sq. In.	Superheat in Branch Pipe Degrees F.
	338	339	340	344	345	347	349	350		220	230
1312	2573	52.83	19358	23542	9.40	9.15	682.4	62.15	Baldwin	178.0	36.0
1316	2547	52.30	19493	23732	9.47	9.32	687.9	66.28	"	178.5	27.1
1313	3259	66.92	23126	28158	11.24	8.64	816.2	58.69	"	177.9	43.1
1314	4897	100.55	29386	35724	14.26	7.30	1035.5	49.59	"	174.6	48.8
1315	6139	126.06	34048	41359	16.51	6.74	1198.8	45.78	"	154.8	45.5

TEST NUMBER	ENGINE PERFORMANCE: Dry Steam to Engines, Pounds per Hour	Indicated Horse Power	Dry Fuel per Indicated Horse Power Hour, Pounds	Dry Steam per Indicated Horse Power Hour, Pounds		LOCOMOTIVE PERFORMANCE: Drawbar Pull, Pounds	Dynamometer or Drawbar Horse Power	Dry Fuel per Dynamom. Horse Power Hour, Pounds	Dry Steam per Dynamom. Horse Power Hour, Pounds	Machine Efficiency of Locomotive, Per Cent.	Thermal Efficiency of Locomotive, per Cent., (Based on Fuel)	Temp. of Steam in branch pipe Degrees F
	214	379	380	381		265	383	384	385	398	399	
1312	19051	745.9	3.4	25.54		17155	610.0	4.22	31.23	81.8	4.24	414.4
1316	19231	774.9	3.3	24.82		18017	640.7	3.98	30.02	82.7	4.71	405.7
1313	22800	910.2	3.6	25.05		21642	769.6	4.23	29.63	84.6	4.23	421.4
1314	29010	1211.0	4.0	23.96		23810	1058.4	4.63	27.41	87.4	3.87	415.6
1315	33636	1264.4	4.9	26.60		20393	1078.8	5.64	36.92	86.0	3.17	413.5

BOILER PRESSURE 180

Table V.

Superheater in use. Steam pressure 180 pounds.

M. P. 394 A—Sixth Sheet
8 x 10½

11-9-10

PENNSYLVANIA RAILROAD COMPANY

Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company.

TEST DEPARTMENT

AVERAGE RESULTS OF LOCOMOTIVE TESTS

LOCOMOTIVE:
TYPE 2-8-0
CLASS H6b.25 in.Cylinders
NUMBER 2846

Bulletin No.13
FUEL: Jamison Coal

SUBJECT: Smokebox Superheater,Trials With Saturated Steam ALTOONA, PA., 4-17-1909

TEST NUMBER	RUNNING CONDITIONS: TEST DESIGNATION	Duration of Test, Hours	Miles per Hour	Throttle Opening, Full or Partial	Actual Cut-off Per Cent., H. P. Cylinders	Temp.of Smoke-box Degrees F	BOILER PERFORMANCE: Pressure in Boiler, Lbs. per Sq. Inch	Draft in Smoke Box, Inches of Water	Draft in Ash Pan, Inches of Water	Calorific Value of Dry Fuel, B. T. U. per Lb.	Cinders Collected in Smoke Box, Pounds per Hour
	R. P. M. Cut-off Throttle	196	199	203	268 to 271		217	222	225	248	238
1329	80-30-F	2	13.34	Full	28.6	520	180.7	2.2	.1	13697	76
1330	80-40-F	2	13.34	"	35.1	540	181.3	2.9	.1	13697	100
1331	100-45-F	2	16.67	"	42.8	428	177.5	4.7	.2	13697	189

TEST NUMBER	BOILER PERFORMANCE: Dry Fuel Fired per Hour, Pounds	Dry Fuel per Hour, Pounds per Sq. Ft. of Grate	Water Delivered to Boiler, Pounds per Hour	Equivalent Evaporation from and at 212° F., Pounds: Per Hour	Per Hour per Sq. Ft. of Fire Heating Sur.	Per Pound of Dry Fuel	Boiler Horse Power (34½ U. of E.)	Efficiency of Boiler, Based on Fuel		ENGINE PERFORMANCE: Pressure in Branch Pipe, Pounds per Sq. In.	Superheat in Branch Pipe Degrees F.
	338	339	340	344	345	347	349	350		220	230
1329	2471	50.74	19553	23662	9.44	9.58	685.9	67.55		178.5	
1330	3179	65.28	23481	28446	11.35	8.95	824.5	63.11		178.6	
1331	4613	94.72	31448	38066	15.19	8.25	1103.4	58.17		175.7	

TEST NUMBER	ENGINE PERFORMANCE: Dry Steam to Engines, Pounds per Hour	Indicated Horse Power	Dry Fuel per Indicated Horse Power Hour, Pounds	Dry Steam per Indicated Horse Power Hour, Pounds		LOCOMOTIVE PERFORMANCE: Drawbar Pull, Pounds	Dynamometer or Drawbar Horse Power	Dry Fuel per Dynamom. Horse Power Hour, Pounds	Dry Steam per Dynamom. Horse Power Hour, Pounds	Machine Efficiency of Locomotive, Per Cent.	Thermal Efficiency of Locomotive, per Cent., (Based on Fuel)	Temp. of Steam in branch Pipe Degrees F
	214	379	380	381		265	383	384	385	398	399	
1329	19238	770.2	3.2	24.98		17799	632.9	3.9	30.40	82.2	4.76	374.0
1330	23169	942.6	3.4	24.58		22377	795.7	4.0	29.12	84.4	4.65	373.8
1331	31030	1206.2	3.8	25.73		23398	1040.0	4.4	29.84	86.2	4.18	372.0

BOILER PRESSURE 180

Table VI.

Tests with superheater removed. Steam pressure 180 pounds.

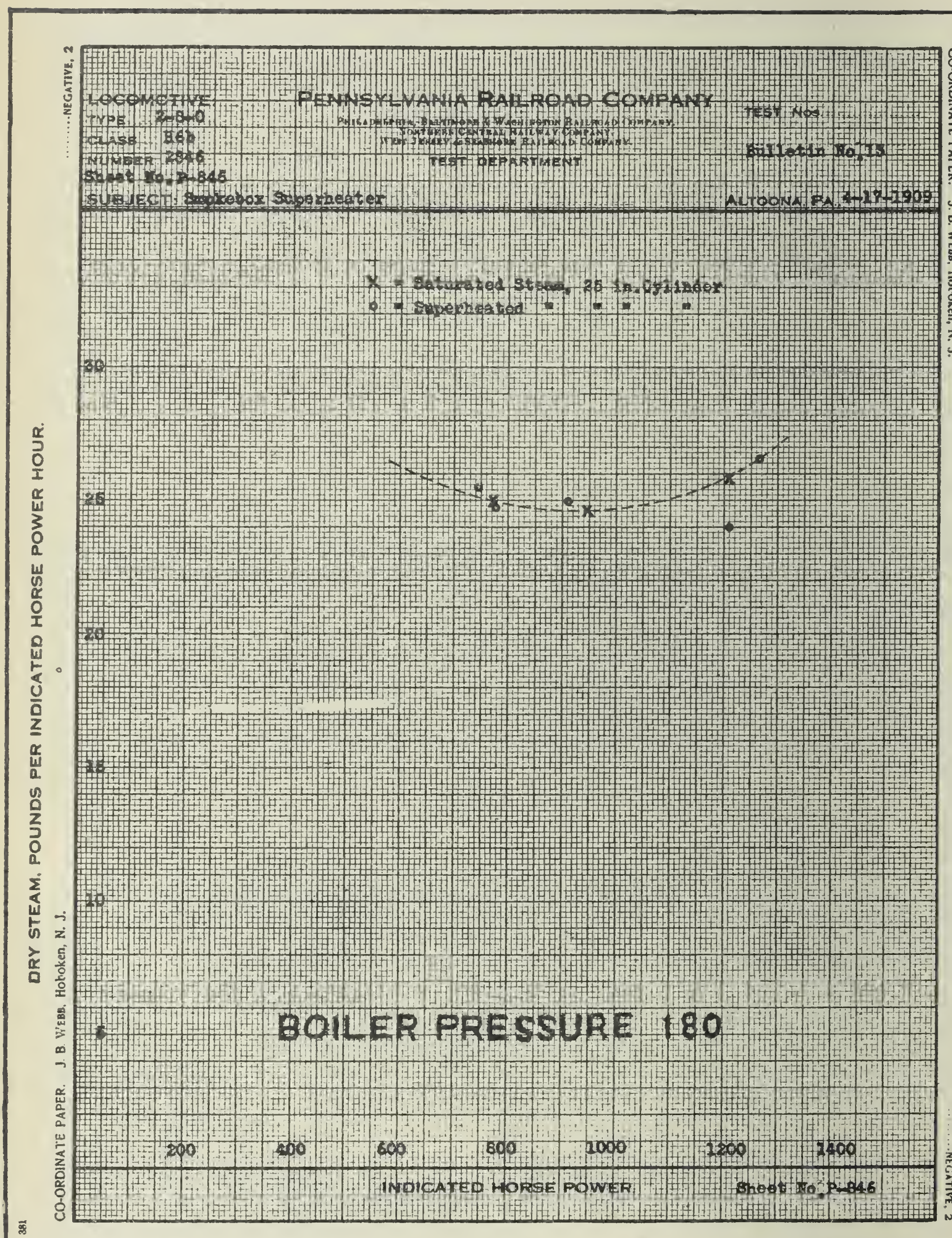


Fig. 14.

STEAM PER INDICATED HORSE-POWER.

Boiler pressure 180 pounds. There is no saving by superheating under these conditions.

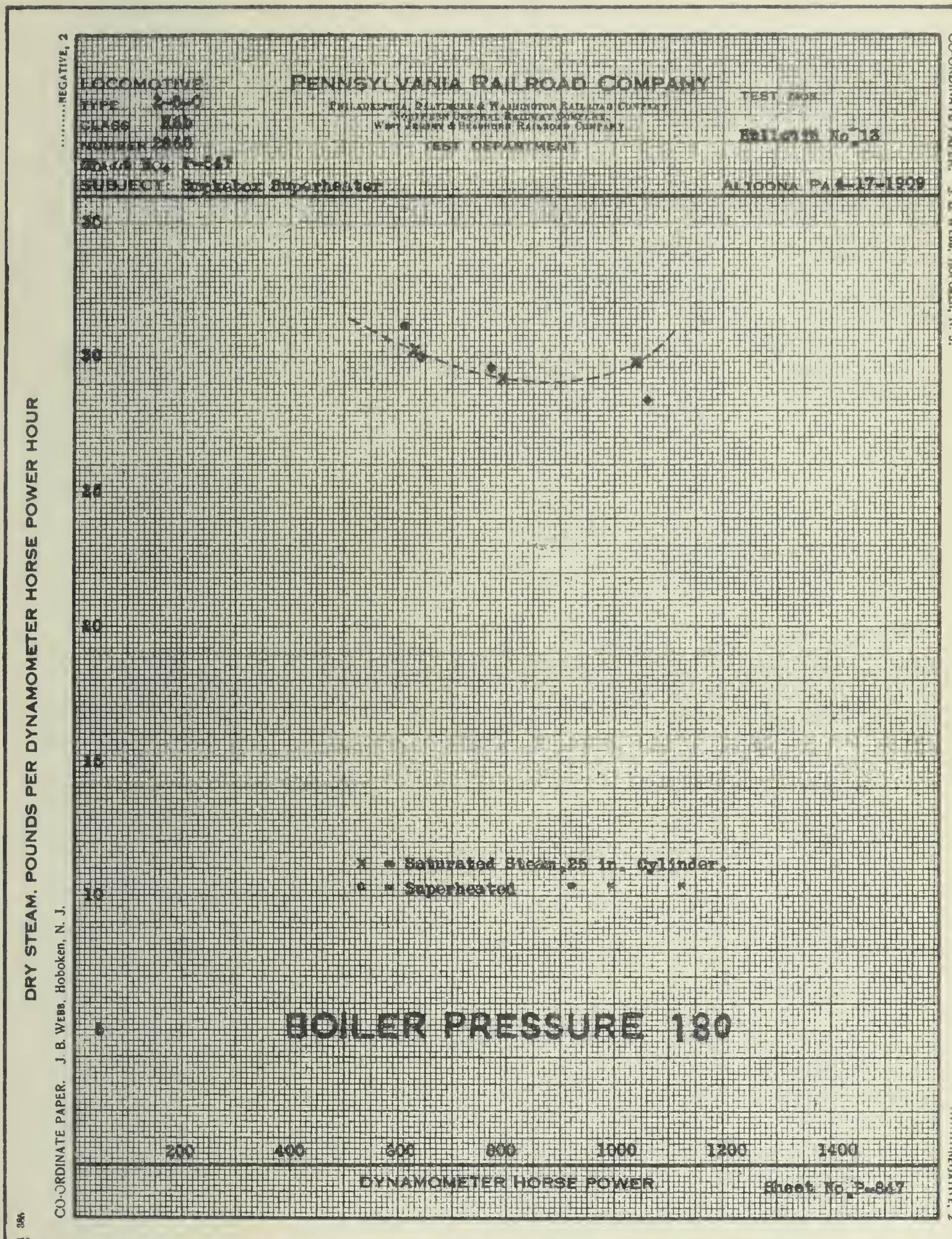


Fig. 15.
STEAM PER DYNAMOMETER HORSE-POWER.
Boiler pressure 180 pounds.

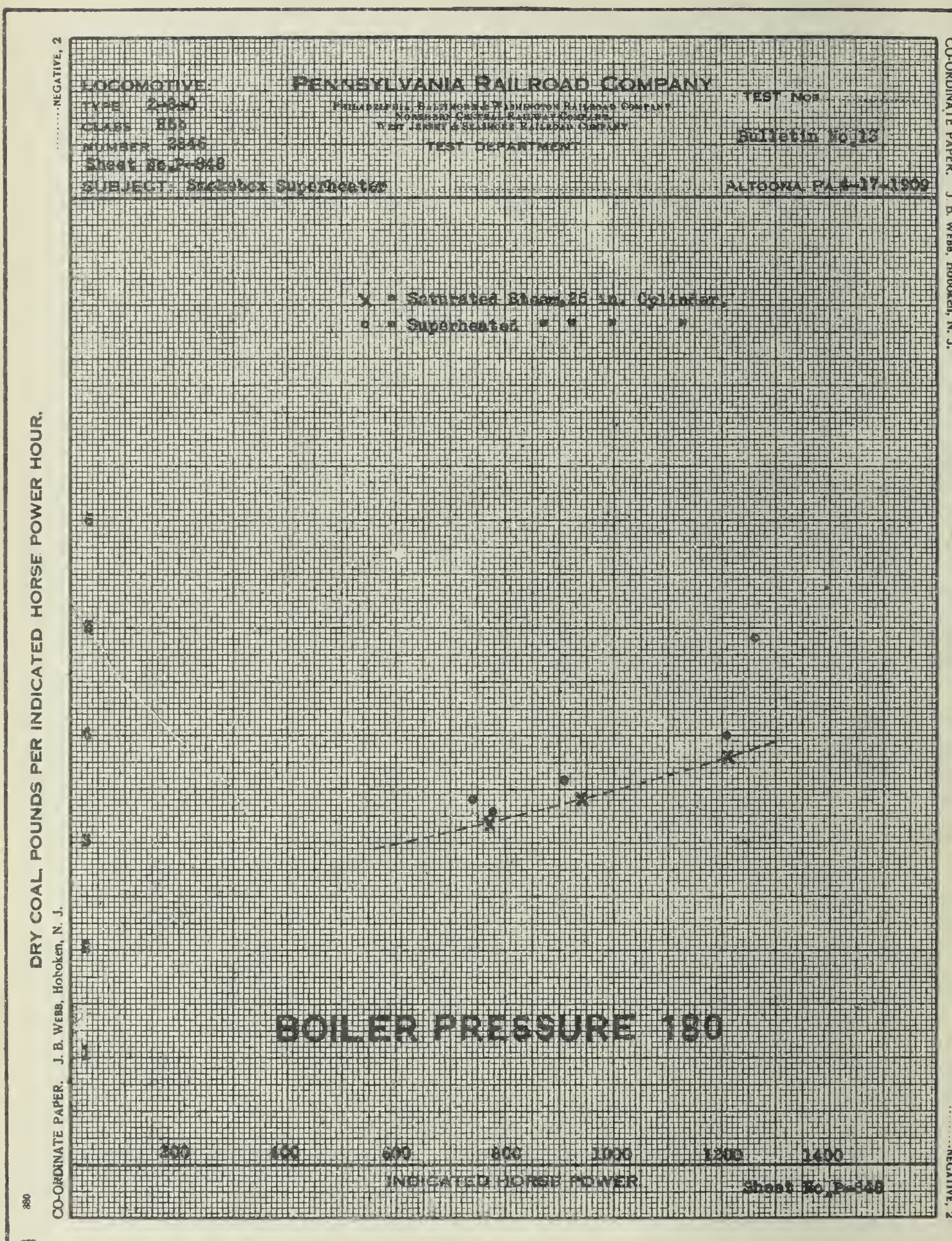


Fig. 16.

COAL PER INDICATED HORSE-POWER.

Boiler pressure 180 pounds.

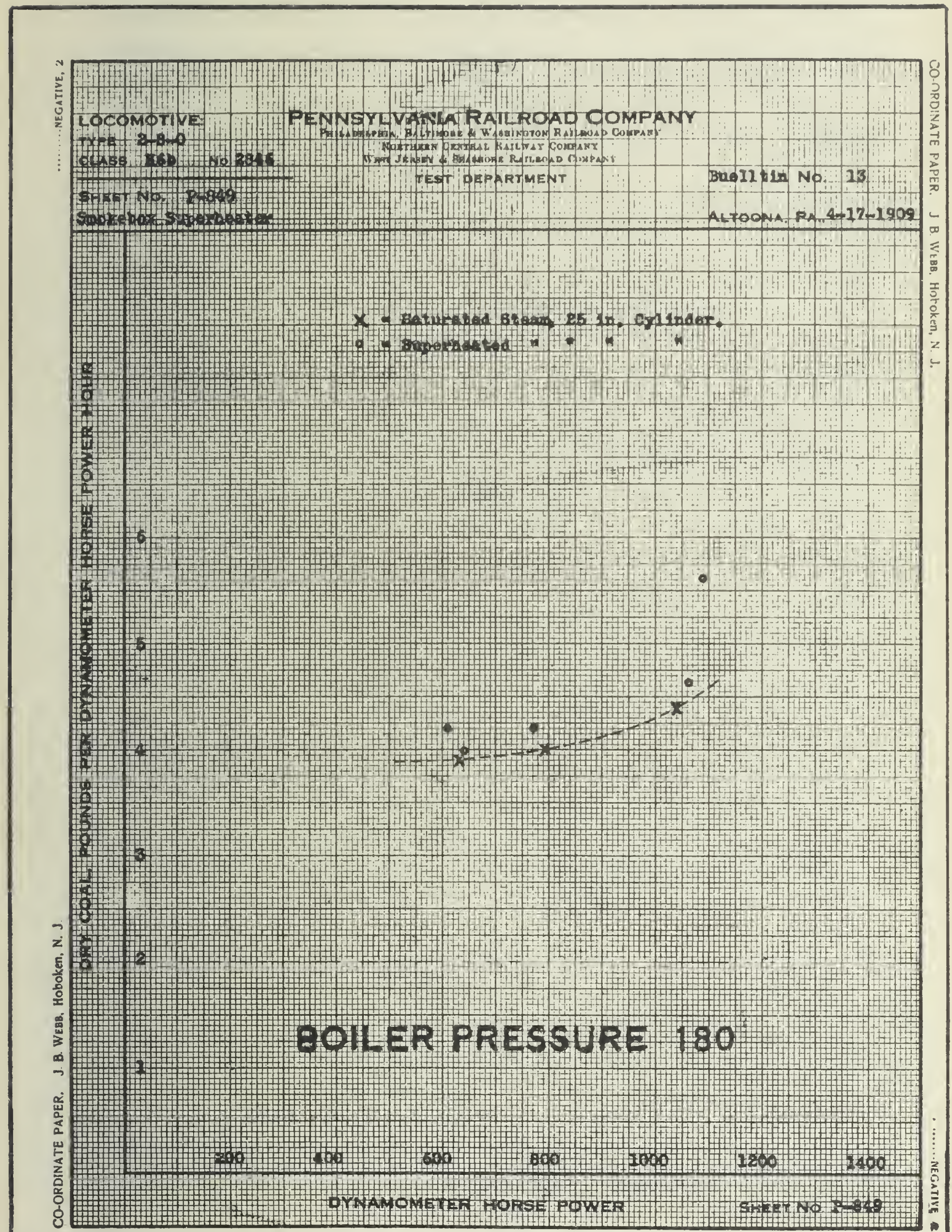


Fig. 17.

COAL PER DYNAMOMETER HORSE-POWER.

Boiler pressure 180 pounds. There is no saving in coal with this boiler pressure.

The superheat ranged from 27 to 48 degrees.

39. The ratio of the mean effective pressures when each locomotive cuts-off at about 36 per cent. is 1.59 when the pressure is 160 pounds. When the pressure is raised to 180 pounds, this ratio becomes 1.38.

40. At 100 revolutions and 50 per cent. cut-off, the drawbar pull of the superheater locomotive is 23135 pounds with 160 pounds pressure, while for the same speed and cut-off much shorter, or about 46 per cent., the pull for the H6b at 205 pounds is 25659 pounds.

Baffling Action of Superheater.

41. In Figs. 18 and 19 the curves show the draft conditions with this superheater locomotive, with the superheater in place and with the superheater removed.

42. From the curves for 160 pounds pressure, which was normal pressure for this locomotive, it is very evident that the superheater obstructed the passage for the smokebox gases when the locomotive is forced to its maximum capacity, and this condition is found when the draft in firebox is practically the same whether the superheater is in place or not. This action means that the draft was reduced in return for superheating.

43. At 180 pounds pressure the increased draft in front of the superheater is not quite so great, but it is considerable. This obstruction presented by the superheater undoubtedly caused the lowering of the maximum boiler capacity. Whether or not this loss of draft could be eliminated and still obtain the superheat in the steam, is a question that cannot be determined from the data of the tests. A number of changes were made in the smokebox arrangement to overcome as much of this loss of draft as was possible, without very materially changing the whole scheme.

Indicator Diagrams from the Two Locomotives.

44. In Figs. 20 and 21 indicator diagrams are shown for locomotive 2846 with superheated and with saturated steam. It is very probable with so low a superheat, that the steam has parted with all of it before the point of cut-off is reached, and is in fact saturated steam for the expansion and compression period, and as would be expected, the diagrams are as nearly as possible alike.

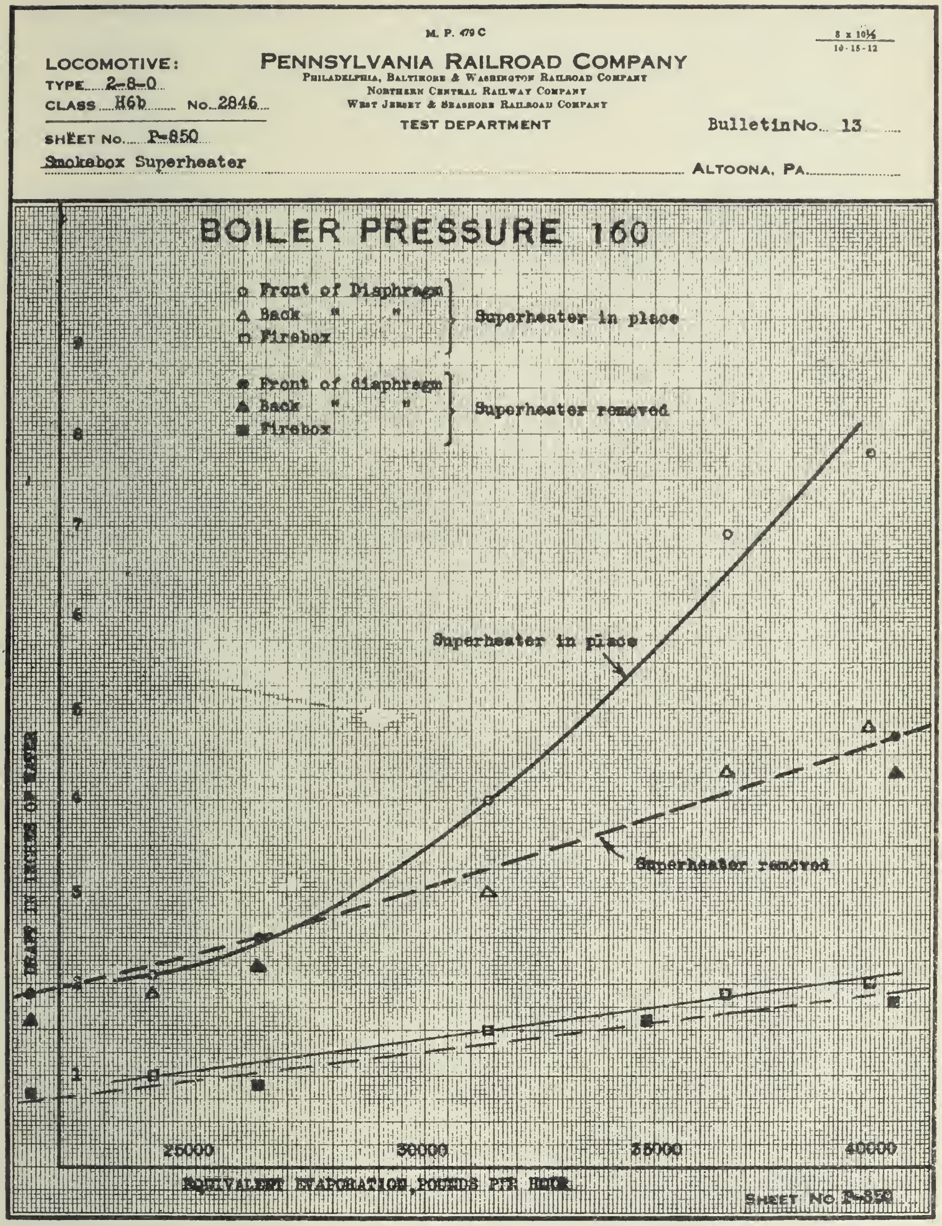


Fig. 18.

DRAFT AND EVAPORATION, 160 POUNDS PRESSURE.

The draft in front of diaphragm is the draft between the superheater and the stack. With the superheater in place in the smokebox, the draft or vacuum in front of it is much increased over what it is with the superheater removed. The draft in the firebox remaining the same under either condition.

M. P. 479 C

8 x 10½
10-15-12

LOCOMOTIVE:
TYPE 2-8-0
CLASS H6b NO. 2846

SHEET NO. P-851

PENNSYLVANIA RAILROAD COMPANY
PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

TEST DEPARTMENT

Bulletin No. 13

Smokebox Superheater.

ALTOONA, PA.

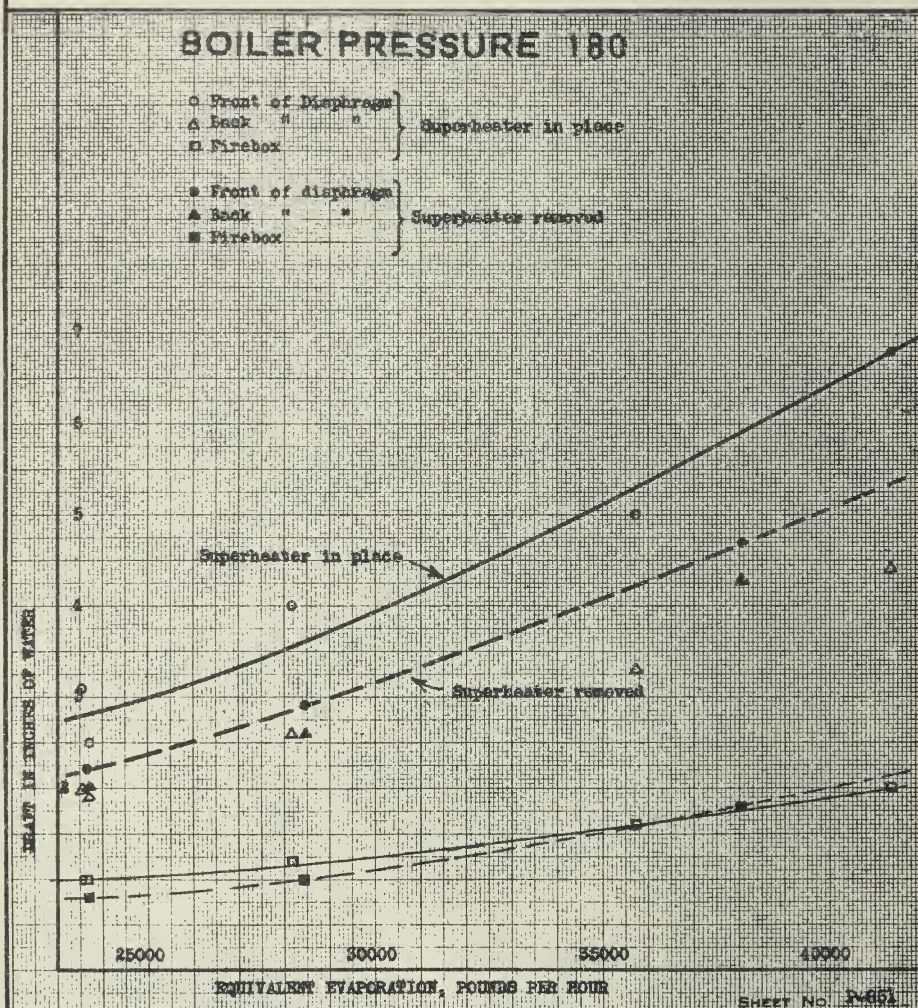


Fig. 19.

DRAFT AND EVAPORATION, 180 POUNDS PRESSURE.

This shows the higher draft in front of the superheater, but to a less extent than in Fig. 18.

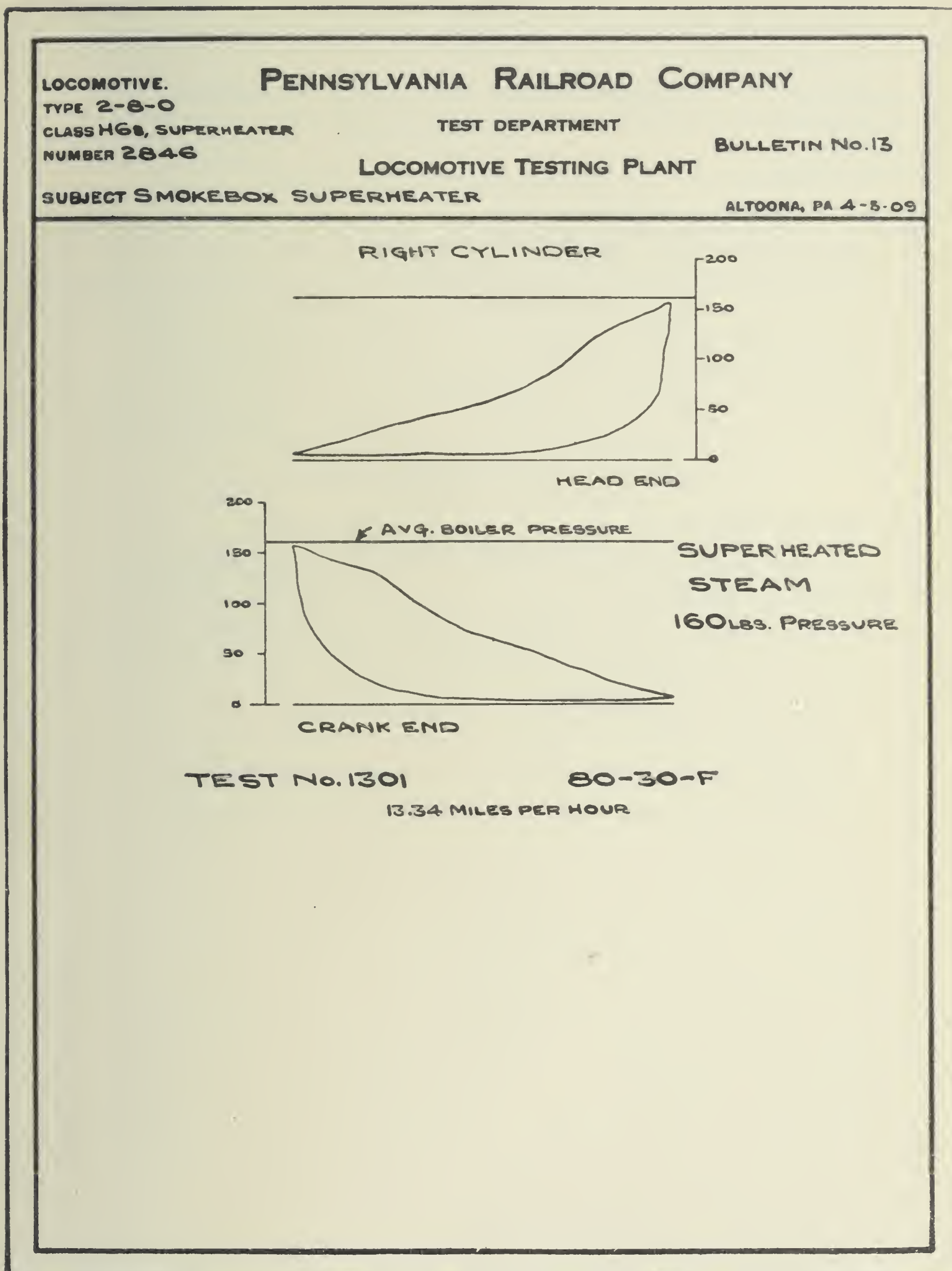


Fig. 20.
TYPICAL INDICATOR DIAGRAMS.
Superheated Steam at 160 pounds pressure.

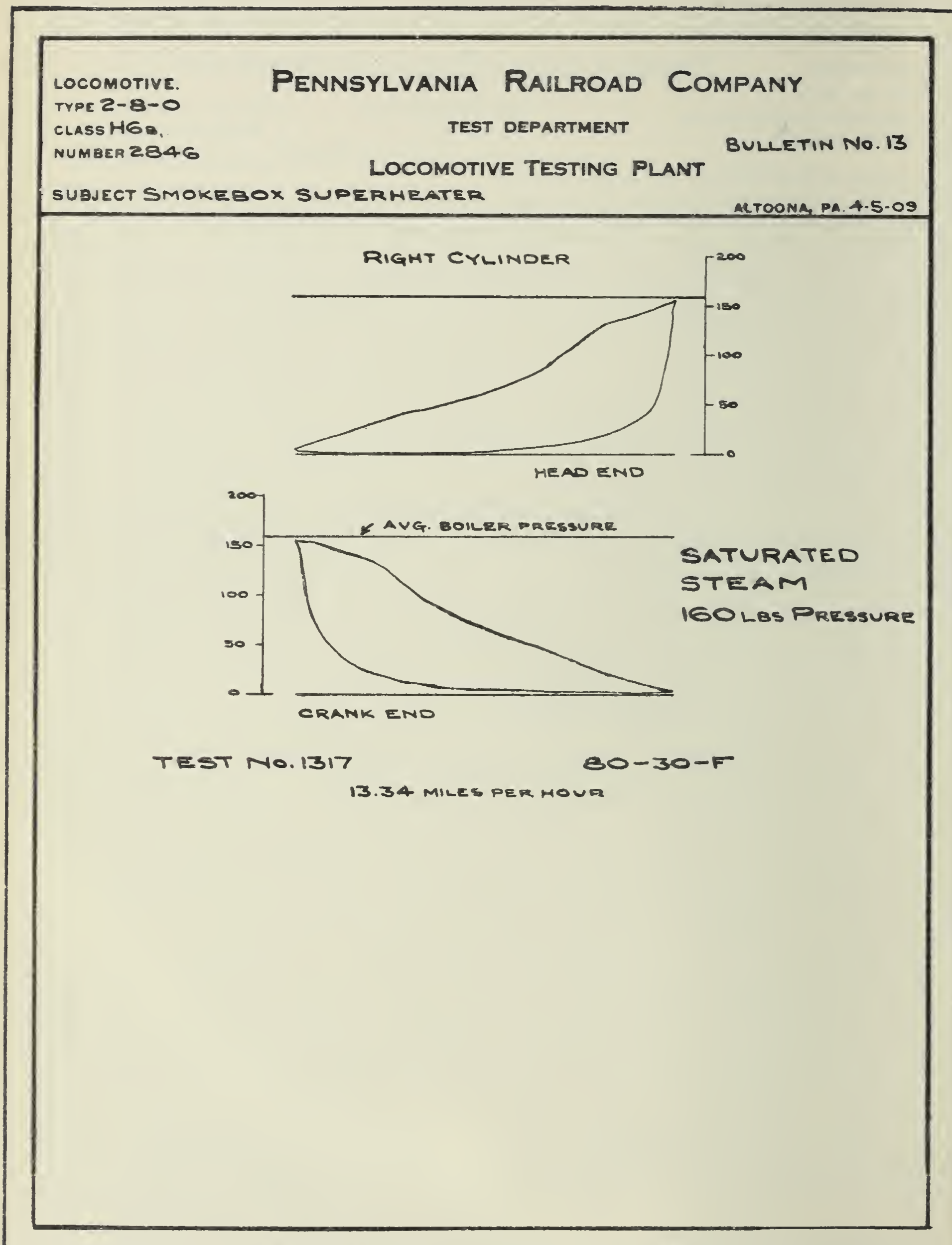


Fig. 21.

TYPICAL INDICATOR DIAGRAMS.

Saturated steam at 160 pounds pressure. These diagrams, except for superheat, were made under the same conditions as those shown in Fig. 20. There is little or no difference in the form of diagram for superheated and saturated steam.

45. There is noticeable in this locomotive a very decided drop in pressure during admission. This fact may account, largely, for the low drawbar pull of the locomotive as compared with the H6b class. The valves and ports of the two locomotives are the same. The difference between the cylinders is in diameter of cylinder only.

46. In Fig. 22 indicator diagrams for the two locomotives are shown. For the H6b class 2860, with 205 pounds pressure the indicator spring scale is 140 pounds per inch, while for No. 2846 superheater with 160 pounds pressure, the scale is 120 pounds per inch.

47. The admission line for the 2860 is better maintained than for the superheater locomotive and the compression is much less. The result being a higher mean effective pressure for the regular H6b locomotive.

Life of Superheater.

48. The superheater was removed from this locomotive in April, 1913, and the tubes were found to be so badly corroded as to be unfit for further service. The life that may be expected then, with this form of superheater, is about four years.

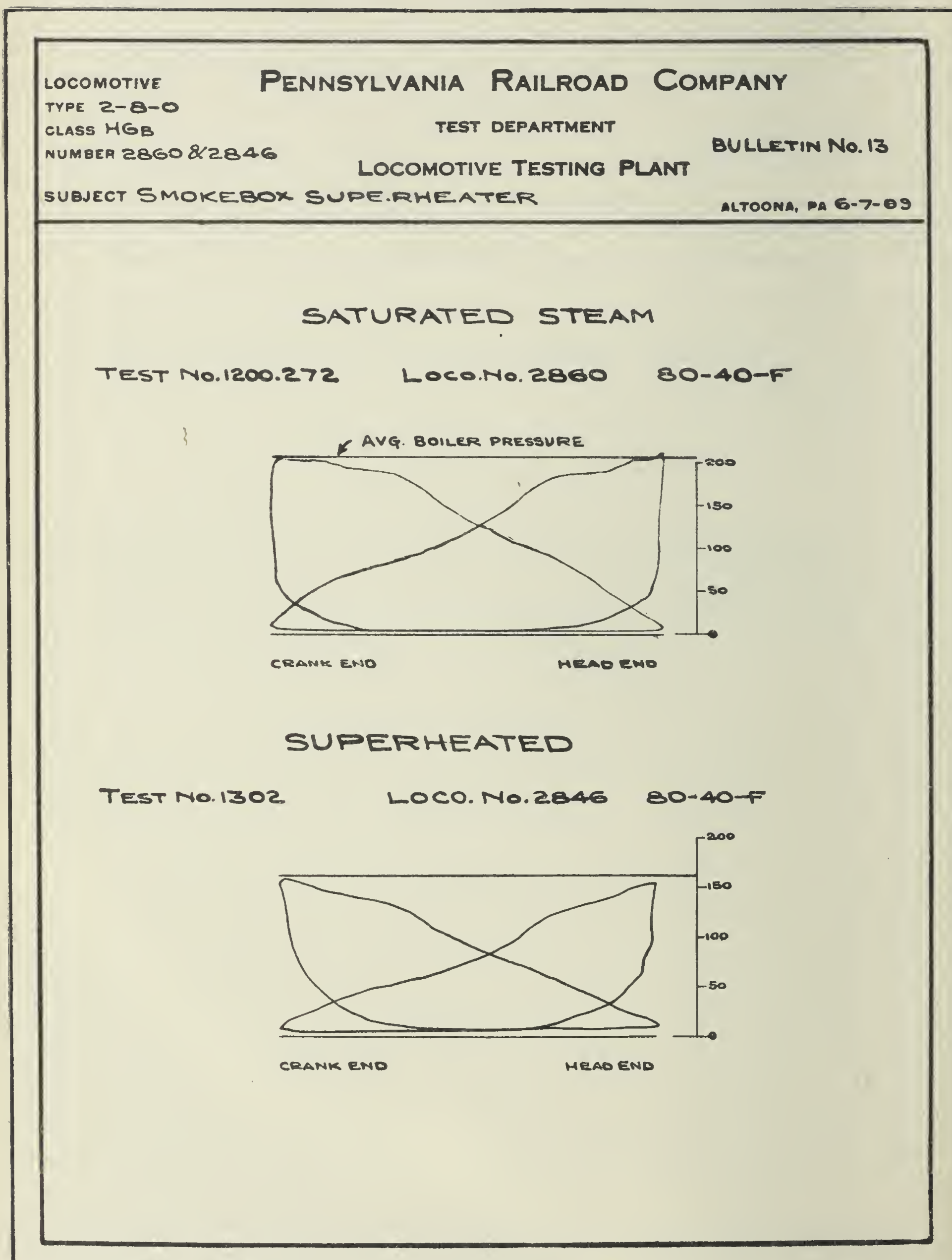


Fig. 22.

TYPICAL INDICATOR DIAGRAMS.

H6b locomotive and saturated steam with cylinders 22 x 28 inch and H6b locomotive and superheated steam with cylinders 25 x 28-inch.

M. P. 394 A—Sixth Sheet
8 x 10½

11-6-10

PENNSYLVANIA RAILROAD COMPANY

Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company

TEST DEPARTMENT

AVERAGE RESULTS OF LOCOMOTIVE TESTS

LOCOMOTIVE:
TYPE 2-8-0
CLASS H6b
NUMBER 2860

Bulletin No. 13
FUEL: Jamison Coal

SUBJECT: Saturated Steam

ALTOONA, PA., 5-24-1909

TEST NUMBER	RUNNING CONDITIONS						BOILER PERFORMANCE				
	TEST DESIGNATION	Duration of Test, Hours	Miles per Hour	Throttle Opening, Full or Partial	Actual Cut-off Per Cent., H. P. Cylinders	Temp. of Smoke-box Degrees F.	Pressure in Boiler, Lbs. per Sq. Inch	Draft in Smoke Box, Inches of Water	Draft in Ash Pan, Inches of Water	Calorific Value of Dry Fuel, B. T. U. per Lb.	Cinders Collected in Smoke Box, Pounds per Hour
	R. P. M. Cut-off Throttle	196	199	203	268 to 271		217	222	225	248	238
1200.276	80-20-F	2.25	13.0	Full	19.2	605	204.6	1.3	.1	13176	21
1200.271	80-30-F	3.0	13.0	"	31.4	675	204.6	2.6	.1	13176	26
1200.272	80-40-F	2.5	13.0	"	38.9	718	204.8	3.4	.1	13176	31
1200.274	100-45-F	2.0	16.25	"	45.7	789	204.2	5.5	.2	14137	104
1200.275	120-40-F	2.0	19.5	"	38.9	784	204.5	5.2	.2	14137	79
1200.273	120-45-F	1.0	19.5	"	45.7	804	184.7	6.2	.2	13176	337

TEST NUMBER	BOILER PERFORMANCE									ENGINE PERFORMANCE	
	Dry Fuel Fired per Hour, Pounds	Dry Fuel per Hour, Pounds per Sq. Ft. of Grate	Water Delivered to Boiler, Pounds per Hour	Equivalent Evaporation from and at 212° F., Pounds: Per Hour	Per Hour per Sq. Ft. of Fire Heating Sur.	Per Pound of Dry Fuel	Boiler Horse Power (34½ U. of E.)	Efficiency of Boiler, Based on Fuel		Pressure in Branch Pipe, Pounds per Sq. In.	Superheat in Branch Pipe Degrees F.
	338	339	340	344	345	347	349	350		220	230
1200.276	1734	35.64	13890	16669	6.65	9.61	483.2	70.44			
1200.271	2593	53.29	19628	23750	9.48	9.16	688.4	67.14			
1200.272	3289	67.57	24036	29104	11.62	8.85	843.6	64.87			
1200.274	5092	104.65	31731	38409	15.33	7.54	1113.3	51.51			
1200.275	4950	101.73	31111	37632	16.02	7.60	1090.7	51.92			
1200.273	5738	117.92	33141	40038	15.98	6.98	1160.5	51.16			

TEST NUMBER	ENGINE PERFORMANCE					LOCOMOTIVE PERFORMANCE						
	Dry Steam to Engines, Pounds per Hour	Indicated Horse Power	Dry Fuel per Indicated Horse Power Hour, Pounds	Dry Steam per Indicated Horse Power Hour, Pounds		Drawbar Pull, Pounds	Dynamometer or Drawbar Horse Power	Dry Fuel per Dynamom. Horse Power Hour, Pounds	Dry Steam per Dynamom. Horse Power Hour, Pounds	Machine Efficiency of Locomotive, Per Cent.	Thermal Efficiency of Locomotive, per Cent., (Based on Fuel)	
	214	379	380	381		265	383	384	385	398	399	
1200.276	13061	520.2	3.3	25.11		12014	428.5	4.1	30.48	82.4	4.75	
1200.271	19387	817.6	3.2	23.71		20234	701.4	3.7	27.64	85.8	5.22	
1200.272	23723	963.5	3.4	24.62		24526	850.2	3.9	27.90	88.2	4.99	
1200.274	31347	1248.9	4.1	25.10		25659	1111.8	4.6	28.19	89.0	3.93	
1200.275	30723	1252.8	4.0	24.52		20998	1091.8	4.5	28.14	87.1	3.97	
1200.273	32740	1258.8	4.6	26.01		21509	1118.4	5.1	29.27	88.8	3.77	

BOILER PRESSURE 205

Table VII.

Tests of a class H6b locomotive using saturated steam. Cylinders 22 x 28 inch.

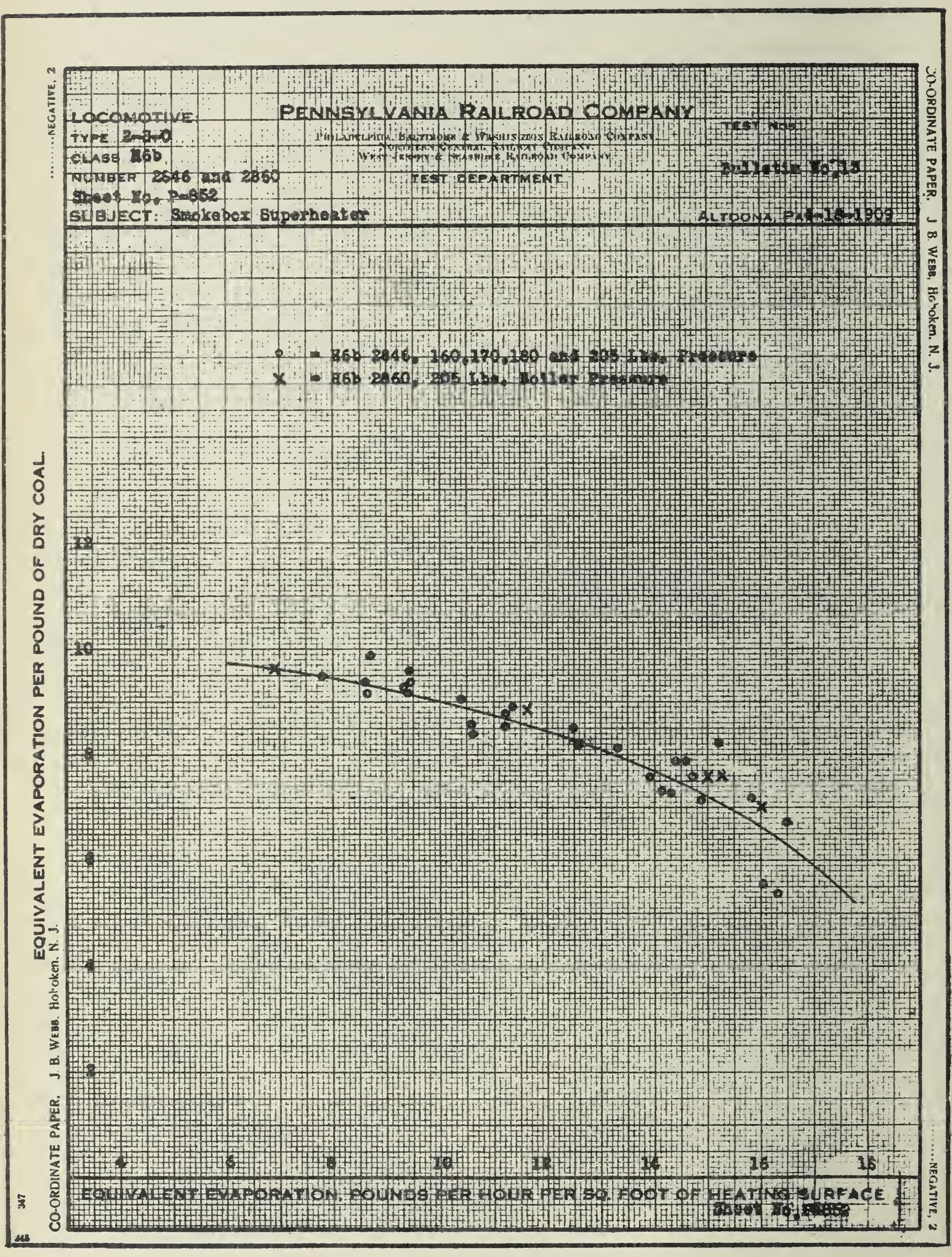


Fig. 23.

The evaporation per pound of coal for the saturated and superheated steam locomotives 2860 and 2846.

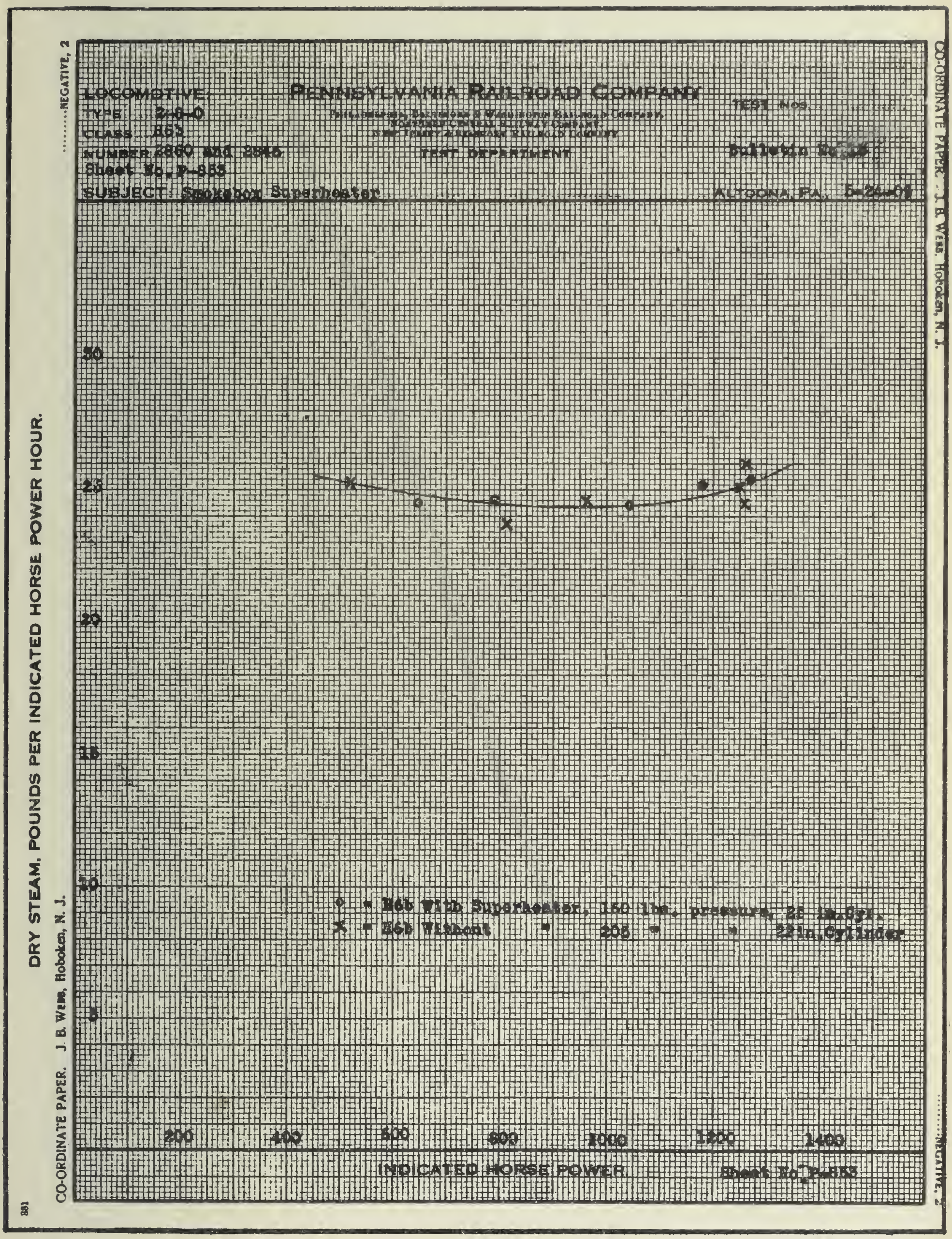


Fig. 24.

STEAM PER INDICATED HORSE-POWER.

The saturated and superheated steam locomotives compared. There is little or no difference in the steam used.

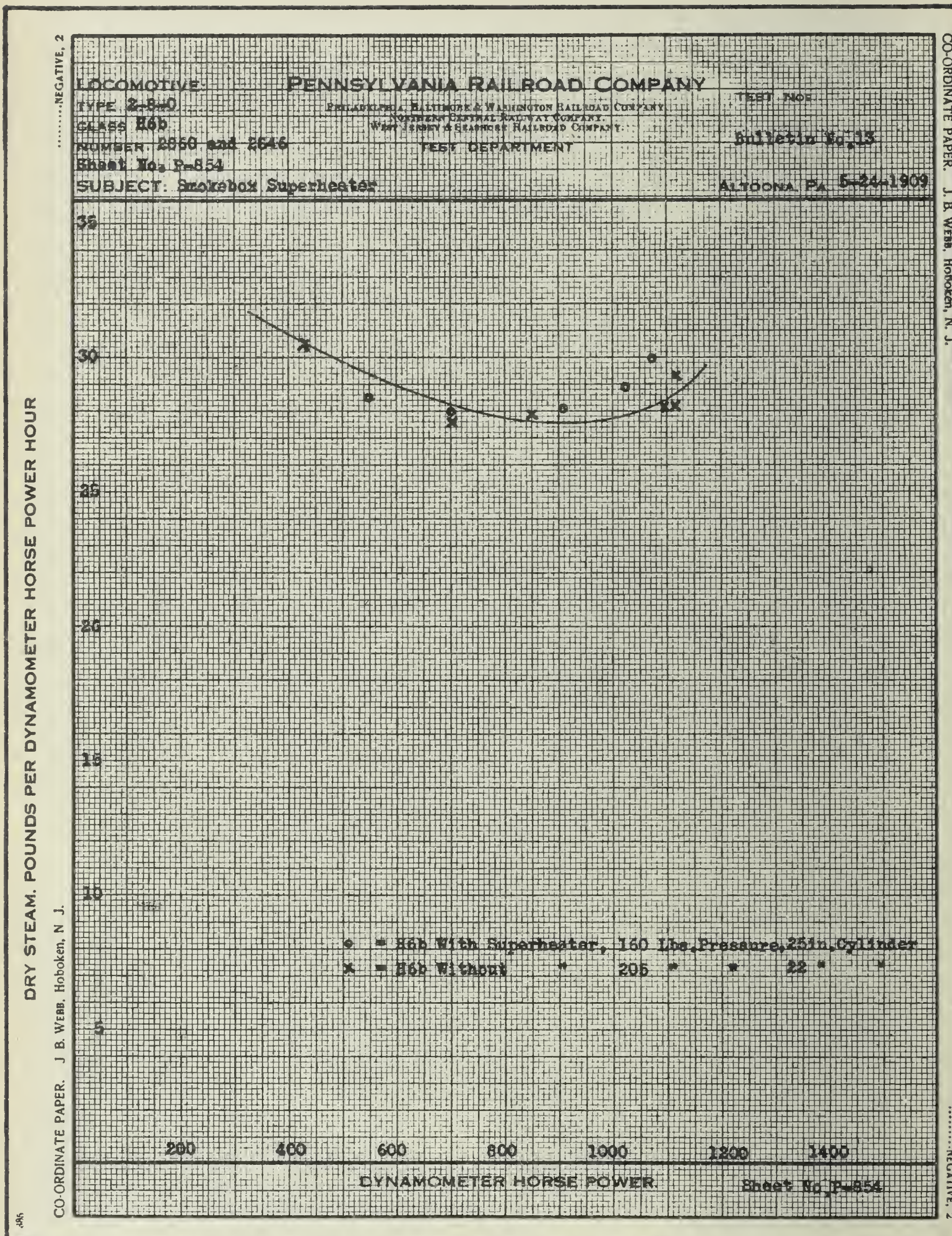


Fig. 25.

STEAM PER DYNAMOMETER HORSE-POWER.

The saturated and superheated steam locomotives compared.

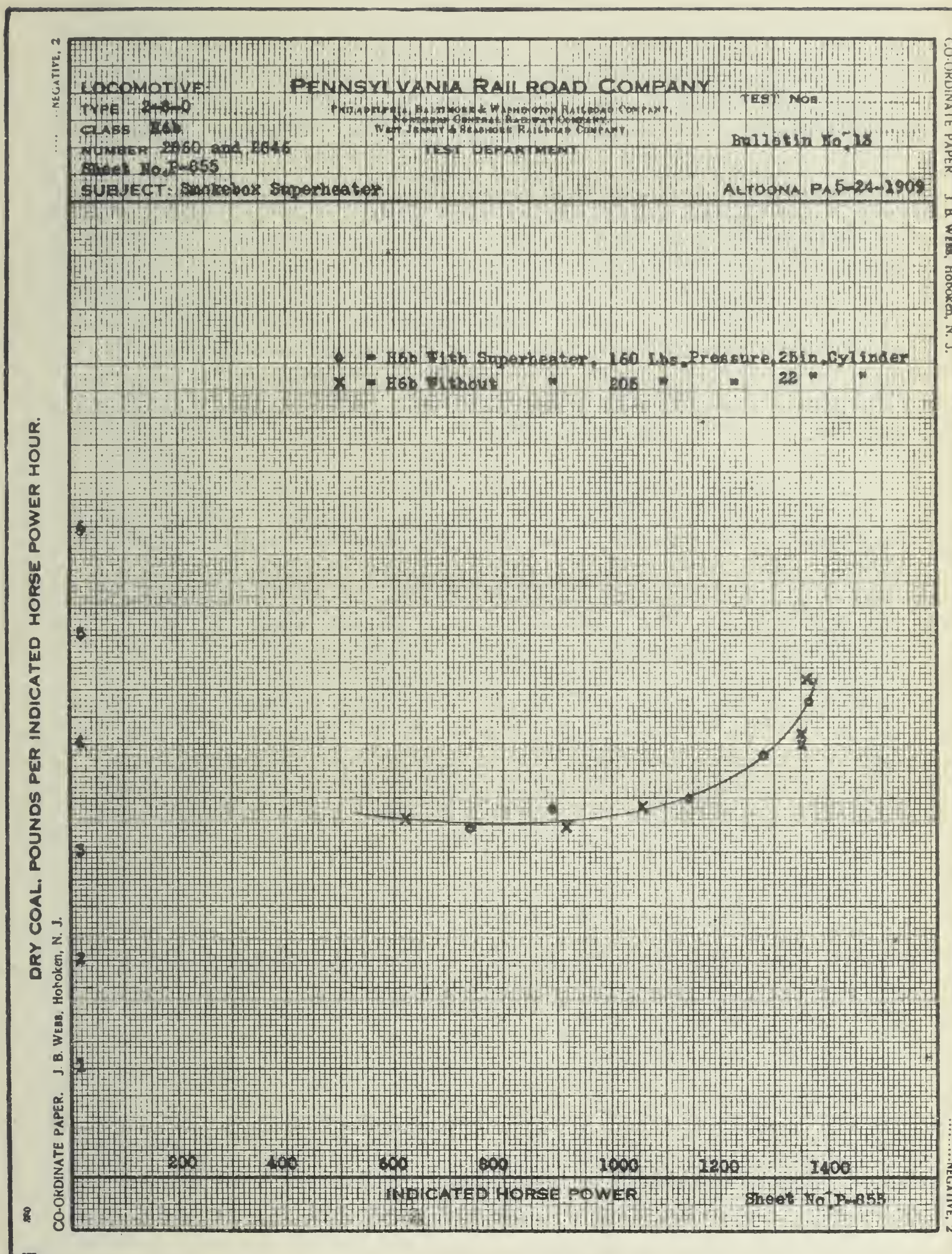


Fig. 26.

COAL PER INDICATED HORSE-POWER.

There is no difference to be noted between the two locomotives.

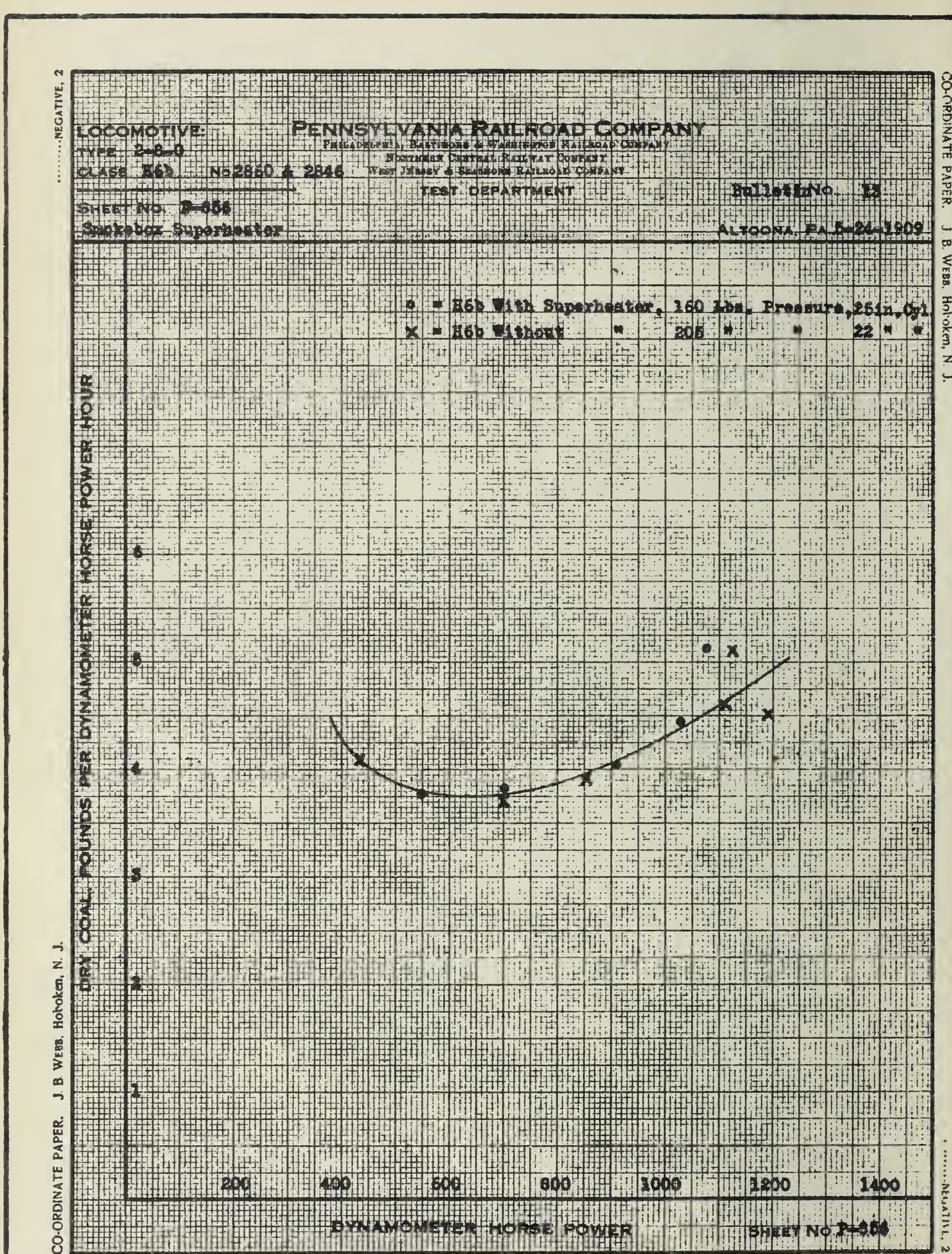


Fig. 27.

COAL PER DYNAMOMETER HORSE-POWER.

No saving can be found from this diagram.

Discussion by Dr. Goss.

49. After the smokebox superheater tests were completed, the report upon them, as embodied in the earlier Bulletin No. 17, was submitted to Dr. W. F. M. Goss, Dean of the College of Engineering, University of Illinois, for his comments and criticisms. Dr. Goss' discussion follows:

A DISCUSSION OF THE DATA PRESENTED BY THE REPORT.

2. "*The Report* deals with tests of 'H6b' locomotive No. 2846 equipped with a smokebox superheater, with tests upon the same locomotive with the superheater removed, and with tests upon 'H6b' locomotive No. 2860 designed for saturated steam, together with certain comparisons and discussions of results.

3. "*The Methods* employed in conducting the tests leave nothing to be desired; the results are consistent and are, I believe, to be accepted as reflecting truthfully the actual performance secured under the several conditions described. The following discussion deals with matters not especially emphasized by the report, and which may therefore be accepted as supplementing the discussions therein presented.

4. "*The Effect of Reducing Pressure upon Locomotives Using Saturated Steam* is disclosed by the results obtained from locomotive No. 2846 after its superheater had been removed, in comparison with results from No. 2860. The steam per horse power hour for the two locomotives is as follows:

Designation of Test.	*No. 2846 Cylinders 25-in. dia. Pressure 160 lbs.*	*No. 2860 Cylinders 22-in. dia. Boiler Pressure 205 lbs.*
80–30–F	27.12	23.71
80–40–F	26.34	24.62
100–45–F	26.36	25.10
Average	26.61	24.48
Difference	2.1	

"The Purdue tests under different pressures ('High Steam Pressures in Locomotive Service,' published by the Carnegie Institution of Washington) give steam consumption as follows:

Boiler pressure 160, steam per h.p.h	26.6
Boiler pressure 200, steam per h.p.h	25.5
Difference	1.1

"It will be seen that the consumption of the P. R. R. locomotive is not greater than that of the Purdue locomotive at 160 pounds pressure, but it is less at the higher pressure. The P. R. R. experiments as disclosed by the report before me show an incresed water consumption of 8 per cent. when the pressure is reduced from 205 pounds to 160. The difference in heat consumption is, of course, less than this, though for some reason not explainable from the data, the difference in fuel consumption is greater. I would call attention to the fact that in the experiments under discussion the reduction in boiler pressure (45 pounds) is considerable, and the loss in efficiency is sufficiently small to sustain my conclusions based on Purdue experiments, namely, that 160 pounds is a good and satisfactory pressure for a simple locomotive, and that when the limit of 200 pounds has been reached it is better to make boilers larger rather than stronger. There is, therefore, nothing disconcerting or unexpected in the results obtained with saturated steam under different pressures as disclosed by the data in hand.

5. "*The Smokebox Superheater* with which No. 2846 was equipped, supplied the cylinders with steam superheated to varying degrees depending upon the running conditions; at low power it was something over 20 degrees, the maximum was less than 60, and the average probably not far from 40 degrees. These values, if considered as results obtained from waste gases alone, as was the case, are good, but in view of the fact that 200 degrees superheat is not uncommon in locomotive service, it would be a mistake to assume that the performance of No. 2846 may be accepted as representative of that which may be obtained through the adoption of superheating as a principle in the development of locomotive design.

6. "Notwithstanding the limitations referred to in the preceding paragraph, the results constitute a remarkable tribute to the value of superheating. They show that the superheating locomotive (No. 2846) with its 25-inch cylinders and 160 pounds boiler pressure gave the same cylinder efficiency as was obtained from the saturated steam locomotive (No. 2860) with its 22-inch cylinders and 205 pounds boiler pressure. So far as economic performance is concerned, the superheater was entirely sufficient to prevent loss when the pressure was reduced from 205 pounds to 160 pounds. Obviously, a superheater which would have given a higher degree of superheat would have permitted a similar reduction in pressure, and at the same time given an increase in cylinder efficiency. These are significant statements; they are sustained by the results of the tests, and are, I believe, sufficiently conservative to be easily subject to verification.

7. "*Power.*—In one respect only are the results obtained from the low pressure (160 pounds) superheating locomotive No. 2846 disappointing when compared with those obtained from the high pressure (205 pounds) saturated steam locomotive No. 2860; namely, with respect to its output of power. An analysis of the data, however, shows that this result is in part apparent only, and it is in part an outgrowth of certain characteristics of the locomotive tested. It is one which should not be interpreted as vitiating, or even as modifying, any general conclusions favorable to the use of superheated steam at moderate pressures which may have been based on tests of other locomotives.

The comparatively low power developed by No. 2846 is due (1) to a difference in steam distribution resulting from the change in pressure (see Par. 44 to 47, of report), and (2) to the interference with the draft-action resulting from the presence of the superheater. The advantage of a comparatively low degree of superheat proved insufficient to offset losses in power arising from these causes.

8. "*Steam Distribution.*—Referring to the changes in steam distribution and their effect upon power, the following facts are to be noted.

"In anticipation of the tests the low-pressure superheating locomotive was given cylinders larger than those of the higher pressure saturated steam locomotive, the increase in cylinder volume being in inverse proportion to the reduction in pressure.

Thus—

Number of locomotive	2846	2860
Pressure	160	205
Cylinder diameter	25	22
Ratio of pressure	1 to	1.28
Ratio of cylinder volume	1.29 to	1

"Ports and port openings were presumably the same for both engines, and it is clear from the data that the effect of supplying cylinders of different volumes through ports of the same dimensions was so slight that differences in results arising from this cause, are hardly measureable. The locomotives involved were, in fact, admirably proportioned for the comparative tests in which they were employed. It appears to have been assumed, however, that two locomotives thus proportioned, when operated at the same cut-off, would develop the same power; that for equal cut-offs the M.E.P. would be directly proportioned to the boiler pressure, hence the locomotives would give the same indicated horse-power and the same pull at the drawbar. The results do not sustain this assumption, and it would be easy to imply from them that in so far as they fail to do so, there is failure of the system of design which is represented by locomotive No. 2846. The real fact is that the assumption, while a perfectly natural one, is not well-grounded. A correct interpretation of the experimental results so far as they relate to cylinder or drawbar power, merely emphasizes this fact. The results rightly interpreted do not prove the superheating locomotive to be deficient in cylinder power. The reason that the fundamental assumption with respect to cylinder power underlying the plan of the tests is not well-grounded will be apparent from the following considerations: As the range of pressure, under which a locomotive is worked, is diminished, other things remaining unchanged, the indicator-cards become more and more 'Lean,' that is, the change in M.E.P. is greater than the change in initial pressure. Such a result may be surmised by an inspection of cards given in Fig. 22 of the report; it would be better shown by plotting any two cards from the same or similar engines which represent the same cut-off but different initial pressures, so that both will have the same total height. The reason is to be found in the fact that the lower the initial pressure, the greater the volume per pound of steam admitted

and the slower the velocity with which it enters: that is, there are two factors which operate to reduce the weight of steam admitted when the initial pressure is reduced.

9. "*Concerning Test Conditions.*—It is obvious from the discussion of the preceding paragraph, that the two locomotives experimented upon, proportioned and operated as described, could not develop the same cylinder power, that in the comparison the low-pressure superheating locomotive was bound to appear at a disadvantage, and hence the fact that the results actually show it to be less powerful should not constitute a source of disappointment.

10. "*A Proposed Basis of Comparison.*—A better basis for comparison would probably have been had if the tests upon the two locomotives had been run at such cut-off as would have resulted in approximately equal cylinder power instead of at equal cut-off. An additional reason for such a basis is to be found in the fact that for best results the cut-off should be lengthened as the pressure is reduced. It should be understood that this suggestion is not offered in criticism of anything that has been done; it becomes easy to offer it after what has been done. It is probable that an attempt to bring power of No. 2846 up to that of No. 2860 would have developed trouble in maintaining the steam supply, but by so doing the one unfavorable factor in the action of No. 2846 would have been located and an opportunity would have been afforded whereby its significance might have been judged.

11. "*The Superheater as a Limiting Factor upon Boiler Capacity* constitutes a subject which may profitably be elaborated from the results of the tests. It is to be noted first that the degree of superheat obtained from the superheater was too slight materially to increase the amount of heat delivered by the boiler. Of all the heat delivered to the branch-pipes, the superheater was responsible for between one and two per cent. On the other hand, the presence in the smokebox of the superheater and baffling associated with it constitutes a serious hindrance to the draft and operates to keep down the capacity of the boiler. The extent of its influence may be judged from the following values which are drawn from the report."

Draft	Equivalent Evaporation Pounds per Hour	
	Superheating Locomotive	Superheating Locomotive Without Superheater
1.5	19,600	
1.9		21,300
2.1	24,000	
2.5		26,000
4.0	31,300	
4.7		40,200
6.9	36,500	
7.8	39,600	

This shows that without the superheater a draft of 4.7 inch was sufficient to evaporate more than 40,000 pounds of water an hour, while with it a draft of 7.8 inch proved insufficient to evaporate this amount. Herein is to be found the most serious question concerning the performance of locomotive No. 2846 which is raised by the data of the report that has been placed before me for review.

A summary of my more important conclusions is as follows:

(*a*) That the low-pressure superheating locomotive operates with substantially the same economy as the high pressure saturated-steam locomotive.

(*b*) That while the cylinder-power and the drawbar pull developed by the low pressure superheating locomotive are lower than those developed by the high-pressure saturated-steam locomotive, the results do not represent the actual relative capacity of the two engines; there is, in fact, no real evidence that the low-pressure superheating locomotive is deficient in cylinder-power or drawbar pull when compared with the high-pressure saturated-steam locomotive.

(*c*) The maximum boiler capacity of the low-pressure superheating locomotive is below that of the high-pressure saturated steam locomotive, and hence at its limit the superheating locomotive is less powerful than the saturated steam locomotive, but the limiting factor is boiler not cylinder capacity.

(*d*) Boiler capacity in the superheating locomotive is impaired by the presence of the superheater and its baffling which interferes with the draft action.

(*e*) There is nothing in the results which should be interpreted as discounting the principle that low-pressure superheated steam may be substituted for higher-pressure saturated steam, without loss in efficiency or power.

(*f*) The results justify raising the question as to whether the increase in economy obtained from the use of the superheater is worth the loss in boiler capacity which the presence of the superheater entails. This is a question not of principle, but one which concerns the merits presented by the design of the particular locomotive tested.

Respectfully submitted,
W. F. M. GOSS.

50. A large number of tests with various cylinder sizes, piston speeds and boiler pressures with and without superheater, would be necessary to establish the fact, "that low pressure superheated steam may be substituted for higher pressure saturated steam without loss in efficiency or power" (summary *e*).

51. Such an extended series of experiments would not be justified for the following reasons:

I.—The conclusions quoted above appear to assume that all mechanical difficulties now causing a drop in pressure between the boiler and cylinders, and the failure of draft appliances to fully meet the needs of the boiler and the grate for burning coal, can be overcome with this form of superheater.

II.—The application of a smokebox superheater has been shown here to have serious disadvantages as suggested in the

above paragraph and these tests confirm the criticisms by Garbe* when discussing the amount of superheat obtained by this type of superheater, where he says: "The blocking up of the smokebox and the tube plate on the smokebox side is an objectionable feature in superheaters of this type" * * * "as the results obtained stand in no relation to the extra trouble and cost involved in their adoption."

III.—The substitution of the suggested lower boiler pressure when superheating with the necessary proportionally larger cylinders raises the question whether the cylinder performance, in consumption of steam, would be as economical as with smaller cylinders and high pressure.

IV.—The scheme embodied in this locomotive, namely: a reduction in the boiler pressure and an increase in the cylinder size, may be seriously questioned on account of the right of way restrictions limiting the spread of the cylinders and the serious increase in weight of reciprocating parts made necessary by the larger cylinders. For these two reasons, it hardly seems advisable to exploit lower boiler pressures in view of the physical restrictions which now surround the locomotive designer.

V.—The lowering of the boiler pressure when applying a superheater, it has been assumed, would be justified by a decrease in boiler maintenance cost. We have no figures to indicate that there would be any gain in boiler maintenance by such a reduction of the pressure and it is difficult to understand, if a uniform stress is applied to the material entering into the construction of boiler, that there should be any material difference in cost of maintenance, regardless of the pressure, within certain reasonable limits.

Cylinder Drainage Tests.

52. The tests of the Baldwin superheater locomotive No. 2846 indicated that there was a considerable loss due to cylinder condensation, especially when this locomotive with large cylinders was operated without the superheater on saturated steam.

53. This locomotive has cylinders 25 inches in diameter instead of the regular 22 inches of the H6b class.

* "The application of Superheated Steam to Locomotives," by Robert Garbe.

54. It has been thought that if the moisture from condensation could be quickly removed from the bottom of the cylinder, where it was supposed to accumulate, that the dryer surfaces produced would decrease the range of cylinder temperature and improve the performance in water rate.

55. To try the effect of draining the bottom of the cylinder during the whole stroke, the cylinder cocks were removed and pipe nipples screwed in. Over the end of each of these nipples a pipe cap was placed. The pipe caps had holes drilled in them for an outlet to the atmosphere.

56. For the tests on locomotive No. 2846 the outlets used were $\frac{1}{16}$, $\frac{1}{8}$ and $\frac{3}{16}$ inch in diameter, for the tests at 160 pounds pressure. These tests were made at 80 revolutions (13 miles per hour) and a cut-off of 40 per cent., and one of them afterward repeated with a boiler pressure of 205 pounds.

57. The results of the drainage tests of the locomotive with 25-inch cylinders without superheater, are shown in Table VIII and Figs. 28 to 30. It will be seen that with the drain holes in the cylinders, the weight of steam used by the engine is not more, but considerably less, than without the outlets and that holes as large as $\frac{3}{16}$ inch in diameter show an economy in steam.

58. At a boiler pressure of 160 pounds, about 10.5 per cent. more steam is used by the undrained cylinders. This is for the total quantity of steam used.

59. The horse-power of the locomotive is not decreased by the openings, and about 12.9 per cent. more steam is used by the undrained cylinders per indicated horse-power.

60. The discharge from the drain holes was a white vapor, evidently water, with a temperature high enough to cause it to vaporize as it escaped into the lower pressure of the atmosphere.

Tests on H6b Class Locomotive No. 2860.

61. As the results of draining the large cylinders of locomotive No. 2846 were encouraging in showing a considerable saving in steam, a series of tests was made on saturated steam locomotive No. 2860, a regular H6b class, with 22-inch cylinders and a boiler pressure of 205 pounds.

62. The tests were made with orifices of six different sizes in the cylinders varying from $\frac{1}{32}$ inch to $\frac{5}{16}$ inch diameter. The tests were made at cut-offs of 30 and 40 per cent. at 80 revolutions per minute and at 45 per cent. cut-off at 100 revolutions per minute. The same kind of coal was used in all of the tests on No. 2860 and the tests were run for one hour at 80 revolutions and one-half hour at 100 revolutions per minute. It was impossible to make tests for one hour at 100 revolutions on account of the poor quality of the coal. The results are shown on Tables IX to XI and Figs. 31 to 33.

63. While there is a saving in steam and coal by drainage it is small. There is a gradual improvement in the performance as the orifices are increased in diameter with the least quantity of steam used at $\frac{1}{4}$ inch diameter.

Conclusions (Cylinder Drainage).

64. The conclusions are that with cylinders proportioned as in the standard H6b locomotive the saving under the usual running conditions is not sufficient to warrant the placing of drainage holes in the cylinders. With cylinders of larger diameter as in locomotive No. 2846, the advantage of drainage is indicated when using saturated steam. It appears, however, as regards the best performance of a locomotive using saturated steam that proper means of cylinder drainage should be provided if a fair comparison of results is to be made with those of a similar locomotive using superheated steam.

65. With the general use of high temperature fire tube superheaters, cylinder condensation is eliminated and the question of drainage is now of minor importance.

Conclusions (Superheater).

66. The superheat obtained just about overcomes the loss due to the reduction in boiler pressure and in this respect, the locomotive does what is expected of it—it makes possible the carrying of a low boiler pressure with its advantages in a decreased first cost of boiler and of boiler maintenance. This refers to the engines only, and they are found to be working efficiently. The results are disappointing in one respect only, that of output of power, and this is a very vital defect in a freight locomotive—lack of hauling power.

67. It is evident from a consideration of the results of these tests that the boiler of the locomotive is the principal part at fault, and its poor showing is probably due to the baffling action of the superheater in the smokebox, together with a drop in the steam pressure, in its passage through the superheater.

68. If the baffling effect of this form of superheater were decreased by wider spacing of the steam pipes, so that the gases could flow more freely, it is probable that the efficiency of the superheater would be much reduced.

69. These test results should not have the effect of condemning all forms of superheaters for our locomotives, as there is nothing in them that could be taken as casting any doubt on the advantages of superheating as a principal; they do show, however, that a high degree of superheating is very desirable and even necessary to obtain sufficient increase in power to pay the cost of the application of the superheater.

70. The defects of the boiler could have been shown more clearly by a different method of testing, but we believe that nothing would be gained by repeating the tests of this locomotive in its present condition, as the results of the tests contain sufficient information to make clear the limitations of this particular design of superheater.

Recommendations.

71. In view of our successful use of high temperature fire tube superheaters, our recommendation is that no more locomotives be equipped with low temperature smokebox superheaters, as the baffling action on the fire and the low boiler pressure which accompany their use materially decrease the coal burning rate and cause the locomotive to be deficient in power.

C. D. YOUNG,
Engineer of Tests.

Approved:
J. T. Wallis,
General Supt. Motive Power.

Test Department,
Altoona, Penna.,
August 12, 1913.

M. P. 394 A—Sixth Sheet
8 x 10½

11-9-10

PENNSYLVANIA RAILROAD COMPANY

Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company

TEST DEPARTMENT

AVERAGE RESULTS OF LOCOMOTIVE TESTS

LOCOMOTIVE:
TYPE 2-8-0
CLASS H6b,25 in.Cylinder
NUMBER 2846

Bulletin No.13
FUEL:

SUBJECT: Cylinder Drained.

ALTOONA, PA., 4-28-1909

TEST NUMBER	RUNNING CONDITIONS						BOILER PERFORMANCE				
	TEST DESIGNATION	Duration of Test, Hours	Miles per Hour	Throttle Opening, Full or Partial	Actual Cut-off Per Cent., H. P. Cylinders	Diameter of outlet at ecah Cylinder Cock	Pressure in Boiler, Lbs. per Sq. Inch	Draft in Smoke Box, Inches of Water	Draft in Ash Pan, Inches of Water	Calorific Value of Dry Fuel, B. T. U. per Lb.	Cinders Collected in Smoke Box, Pounds per Hour
	R. P. M. Cut-off Throttle	196	199	203	268 to 271		217	222	225	248	238
1318	80-40-F	2	13.34	Full	35.6	None	160.5				
1332	80-40-F	0.5	"	"	36.0	1/16 in.	161.3				
1333	80-40-F	0.5	"	"	35.6	1/8 "	156.9				
1334	80-40-F	0.5	"	"	35.0	5.16 in.	161.1				
1326	80-40-F	2	13.34	"	35.9	None	201.2				
1335	80-40-F	0.5	"	"	35.3	1/8 in.	201.7				

TEST NUMBER	BOILER PERFORMANCE									ENGINE PERFORMANCE	
				EQUIVALENT EVAPORATION FROM AND AT 212° F., POUNDS							
	Dry Fuel Fired per Hour, Pounds	Dry Fuel per Hour, Pounds per Sq. Ft. of Grate	Water Delivered to Boiler, Pounds per Hour	Per Hour	Per Hour per Sq. Ft. of Fire Heating Sur.	Per Pound of Dry Fuel	Boiler Horse Power (34½ U. of E.)	Efficiency of Boiler, Based on Fuel		Pressure in Branch Pipe, Pounds per Sq. In.	Superheat in Branch Pipe Degrees F.
	338	339	340	344	345	347	349	350		220	230
1318			21725	26366							
1332			20344	24524							
1333			19224	23160							
1334			19944	24051							
1326			25910	31455							
1335			24256	29407							

TEST NUMBER	ENGINE PERFORMANCE					LOCOMOTIVE PERFORMANCE						
	Dry Steam to Engines, Pounds per Hour	Indicated Horse Power	Dry Fuel per Indicated Horse Power Hour, Pounds	Dry Steam per Indicated Horse Power Hour, Pounds		Drawbar Pull, Pounds	Dynamometer or Drawbar Horse Power	Dry Fuel per Dynamom. Horse Power Hour, Pounds	Dry Steam per Dynamom. Horse Power Hour, Pounds	Machine Efficiency of Locomotive, Per Cent.	Thermal Efficiency of Locomotive, per Cent., (Based on Fuel)	
	214	379	380	381		265	383	384	385	398	399	
1318	21394	812.2		26.34		19649	698.7		30.62	86.0		
1332	20098	840.8		23.90		20030	712.3		28.22	84.7		
1333	18991	797.3		23.82		19294	686.1		27.68	86.1		
1334	19616	809.0		24.25		19783	703.5		27.88	87.0		
1326	25590	1052.3		24.32		25799	917.4		27.89	87.2		
1335	23963	1050.2		22.82		26027	925.5		25.89	88.1		

Table VIII.

CYLINDERS DRAINED. 25-INCH CYLINDER.

Three sizes of outlet at cylinder cock, saturated steam.

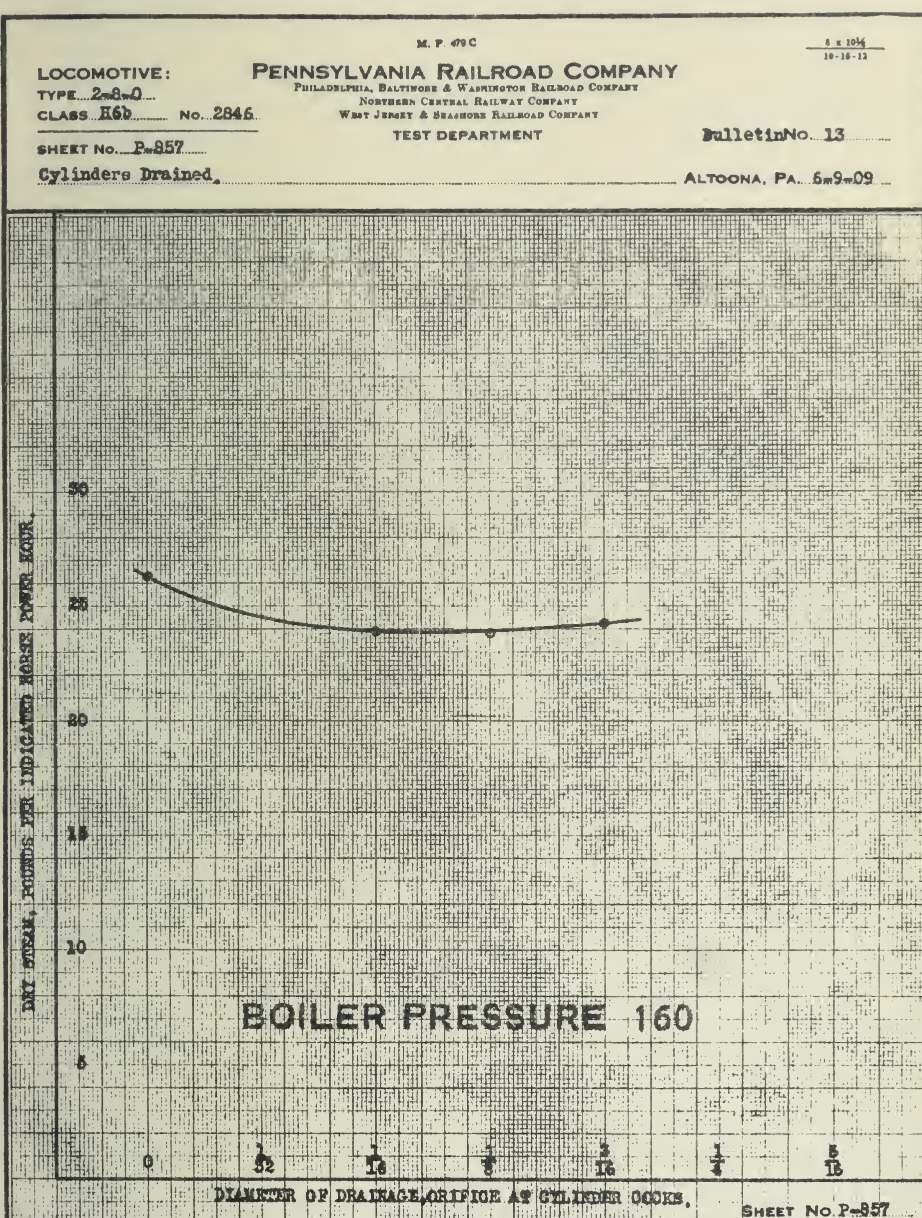


Fig. 28.

CYLINDERS DRAINED.

Steam per horse power with outlets at bottom of cylinder, 25-inch cylinders and saturated steam. Steam pressure 160 pounds. Speed m.p.h., cut-off 40 per cent. There is a decrease in the steam used up to ⅛-inch outlets.

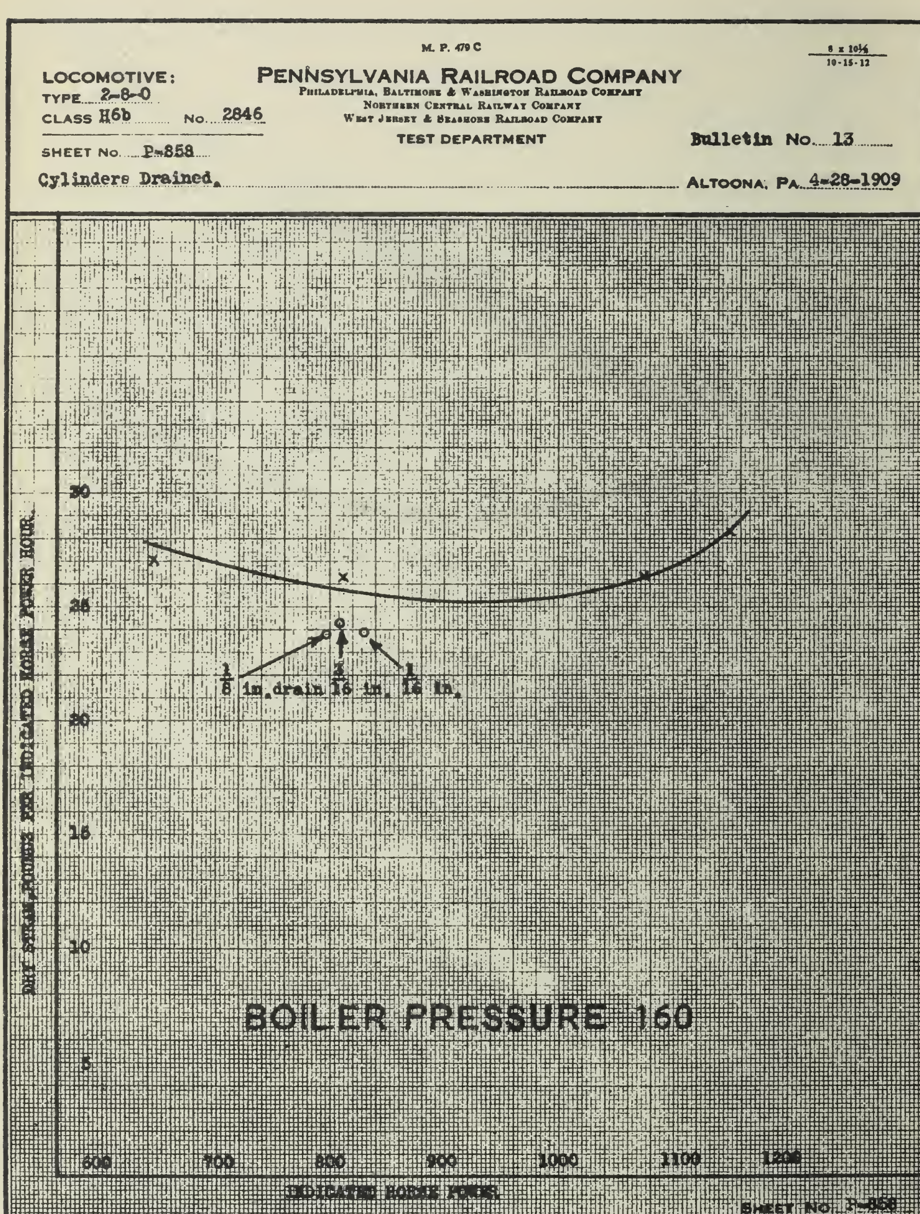


Fig. 29.

CYLINDERS DRAINED.

Steam per horse power with outlets at bottom of cylinder. 25-inch cylinders and saturated steam. Pressure 160 pounds.

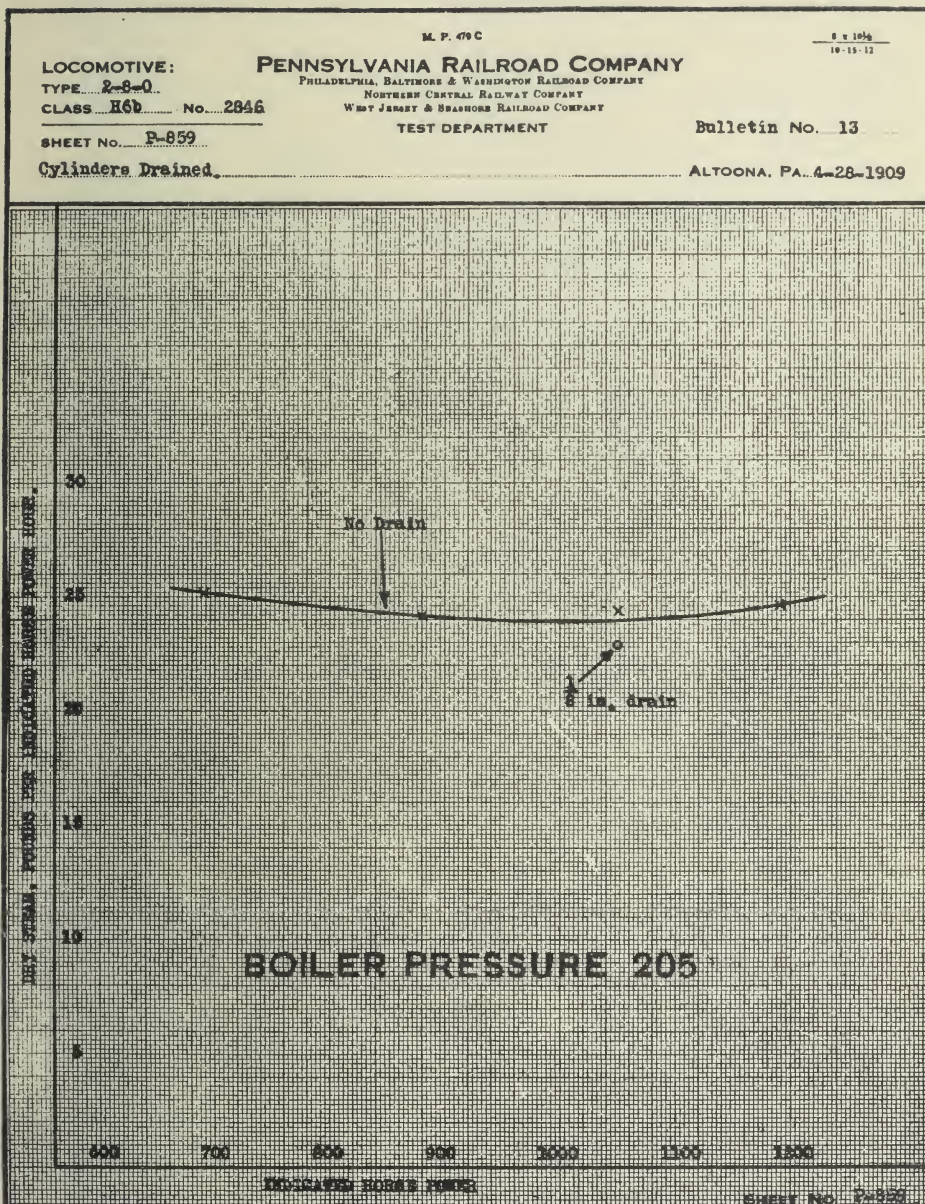


Fig. 30.
CYLINDERS DRAINED.
Steam per horse power. Steam pressure 205 pounds.

M. P. 394 A – Sixth Sheet

11-9-10

PENNSYLVANIA RAILROAD COMPANY

Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company

TEST DEPARTMENT

AVERAGE RESULTS OF LOCOMOTIVE TESTS

Bulletin No. 13

LOCOMOTIVE:
TYPE 2-8-0
CLASS H6b
NUMBER 2860

FUEL: Jamison Coal

SUBJECT: Cylinder Drained.

ALTOONA, PA., 6-8-1909

TEST NUMBER	RUNNING CONDITIONS						BOILER PERFORMANCE				
	TEST DESIGNATION	Duration of Test, Hours	Miles per Hour	Throttle Opening, Full or Partial	Actual Cut-off Per Cent., H. P. Cylinders	Size of Orifice	Pressure in Boiler, Lbs. per Sq. Inch	Draft in Smoke Box, Inches of Water	Draft in Ash Pan, Inches of Water	Calorific Value of Dry Fuel, B. T. U. per Lb.	Cinders Collected in Smoke Box, Pounds per Hour
	R. P. M. Cut-off Throttle	196	199	203	268 to 271		217	222	225	248	238
1200.306	80-30-F	1.0	13.00	Full	31.1	1/32 in	204.4	2.5	0.1	13920	
1200.307	80-30-F	1.0	13.00	"	30.9	1/16 "	204.0	2.5	0.1	13920	
1200.308	80-30-F	1.0	13.00	"	32.0	1/8 "	203.7	2.5	0.1	13920	
1200.309	80-30-F	1.0	13.00	"	30.8	3/16 "	203.9	2.4	0.1	13920	
1200.310	80-30-F	1.0	13.00	"	31.0	1/4 "	204.1	2.3	0.1	13920	
1200.311	80-30-F	1.0	13.00	"	31.5	5/16 "	201.4	2.3	0.1	13920	

TEST NUMBER	BOILER PERFORMANCE									ENGINE PERFORMANCE	
	Dry Fuel Fired per Hour, Pounds	Dry Fuel per Hour, Pounds per Sq. Ft. of Grate	Water Delivered to Boiler, Pounds per Hour	EQUIVALENT EVAPORATION FROM AND AT 212° F., POUNDS: Per Hour	Per Hour per Sq. Ft. of Fire Heating Sur.	Per Pound of Dry Fuel	Boiler Horse Power (34½ U. of E.)	Efficiency of Boiler, Based on Fuel		Pressure in Branch Pipe, Pounds per Sq. In.	Superheat in Branch Pipe Degrees F.
	338	339	340	344	345	347	349	350		220	230
1200.306	2478	50.93	19688	23640	9.44	9.54	685.2	66.19			
1200.307	2479	50.95	19608	23584	9.41	9.51	683.6	65.98			
1200.308	2383	48.97	19608	23596	9.42	9.90	683.9	68.69			
1200.309	2322	47.72	19266	23188	9.26	9.99	672.1	69.31			
1200.310	2289	47.04	19438	23412	9.35	10.23	678.6	70.98			
1200.311	2339	48.07	19243	23150	9.24	9.90	671.0	68.69			

TEST NUMBER	ENGINE PERFORMANCE					LOCOMOTIVE PERFORMANCE						
	Dry Steam to Engines, Pounds per Hour	Indicated Horse Power	Dry Fuel per Indicated Horse Power Hour, Pounds	Dry Steam per Indicated Horse Power Hour, Pounds		Drawbar Pull, Pounds	Dynamometer or Drawbar Horse Power	Dry Fuel per Dynamom. Horse Power Hour, Pounds	Dry Steam per Dynamom. Horse Power Hour, Pounds	Machine Efficiency of Locomotive, Per Cent.	Thermal Efficiency of Locomotive, per Cent., (Based on Fuel)	
	214	379	380	381		265	383	384	385	398	399	
1200.306	19351	808.9	3.06	23.92		20556	733.1	3.38	26.40	90.6	5.41	
1200.307	19190	819.2	3.03	23.43		21068	751.4	3.30	25.54	91.7	5.54	
1200.308	19283	821.8	2.90	23.46		21032	750.1	3.18	25.71	91.3	5.75	
1200.309	18996	810.0	2.87	23.45		20514	731.6	3.17	25.97	90.3	5.77	
1200.310	19101	820.7	2.79	23.27		20784	741.2	3.09	25.77	90.3	5.92	
1200.311	18957	806.9	2.90	23.49		20336	725.3	3.22	26.14	89.9	5.66	

Table IX.

CYLINDERS DRAINED.

H6b locomotive, 22-inch cylinders with outlets at cylinder cocks. 13 miles per hour.

M. P. 804 A—Sixth Sheet
8 x 10½

11-9-10

PENNSYLVANIA RAILROAD COMPANY

Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company

TEST DEPARTMENT

AVERAGE RESULTS OF LOCOMOTIVE TESTS

Bulletin No.13

LOCOMOTIVE:
TYPE 2-8-0
CLASS H6b
NUMBER 2860

FUEL: Jamison Coal

SUBJECT: Cylinder Drained.

ALTOONA, PA., 6-8-1909

TEST NUMBER	RUNNING CONDITIONS						BOILER PERFORMANCE				
	TEST DESIGNATION	Duration of Test, Hours	Miles per Hour	Throttle Opening, Full or Partial	Actual Cut-off Per Cent., H. P. Cylinders	Size of Orifice	Pressure in Boiler, Lbs. per Sq. Inch	Draft in Smoke Box, Inches of Water	Draft in Ash Pan, Inches of Water	Calorific Value of Dry Fuel, B. T. U. per Lb.	Cinders Collected in Smoke Box, Pounds per Hour
	R. P. M. Cut-off Throttle	196	199	203	268 to 271		217	222	225	248	238
1200.300	80-40-F	1.0	13.00	Full	38.7	1/32in.	204.7	3.5	0.1	13920	
1200.301	80-40-F	1.0	13.00	"	40.1	1/16 "	204.6	3.4	0.1	13920	
1200.302	80-40-F	1.0	13.00	"	39.6	1/8 "	203.9	3.5	0.2	13920	
1200.303	80-40-F	1.0	13.00	"	38.9	3/16 "	203.6	3.3	0.1	13920	
1200.304	80-40-F	1.0	13.00	"	38.8	1/4 "	204.3	3.3	0.1	13920	
1200.305	80-40-F	1.0	13.00	"	39.2	5/16 "	205.0	3.4	0.1	13920	

TEST NUMBER	BOILER PERFORMANCE									ENGINE PERFORMANCE	
	Dry Fuel Fired per Hour, Pounds	Dry Fuel per Hour, Pounds per Sq. Ft. of Grate	Water Delivered to Boiler, Pounds per Hour	EQUIVALENT EVAPORATION FROM AND AT 212° F., POUNDS: Per Hour	Per Hour per Sq. Ft. of Fire Heating Sur.	Per Pound of Dry Fuel	Boiler Horse Power (34½ U. of E.)	Efficiency of Boiler, Based on Fuel		Pressure in Branch Pipe, Pounds per Sq. In.	Superheat in Branch Pipe Degrees F.
	338	339	340	344	345	347	349	350		220	230
1200.300	3331	68.46	23810	28622	11.42	8.59	829.6	59.60			
1200.301	3220	66.17	24020	28921	11.54	8.98	838.3	62.31			
1200.302	3302	67.86	23670	28521	11.38	8.64	826.7	59.95			
1200.303	3211	65.99	23330	28100	11.22	8.75	814.5	60.71			
1200.304	3080	63.30	23475	28274	11.29	9.18	819.5	63.69			
1200.305	3062	62.93	23600	28427	11.35	9.28	824.0	64.39			

TEST NUMBER	ENGINE PERFORMANCE					LOCOMOTIVE PERFORMANCE						
	Dry Steam to Engines, Pounds per Hour	Indicated Horse Power	Dry Fuel per Indicated Horse Power Hour, Pounds	Dry Steam per Indicated Horse Power Hour, Pounds		Drawbar Pull, Pounds	Dynamometer or Drawbar Horse Power	Dry Fuel per Dynamom. Horse Power Hour, Pounds	Dry Steam per Dynamom. Horse Power Hour, Pounds	Machine Efficiency of Locomotive, Per Cent.	Thermal Efficiency of Locomotive, per Cent., (Based on Fuel)	
	214	379	380	381		265	383	384	385	398	399	
1200.300	23493	967.2	3.44	24.29		24821	860.4	3.87	27.30	89.0	4.72	
1200.301	23639	976.2	3.30	24.22		25051	868.4	3.71	27.22	89.0	4.93	
1200.302	23354	971.2	3.40	24.05		24556	851.2	3.88	27.44	87.6	4.71	
1200.303	23048	959.5	3.35	24.02		24484	848.7	3.78	27.16	88.5	4.84	
1200.304	23191	972.0	3.17	23.86		24979	865.8	3.56	26.78	89.1	5.14	
1200.305	23302	969.7	3.16	24.03		24900	863.1	3.55	27.00	89.0	5.15	

Table X.
CYLINDERS DRAINED.
H6b locomotive, 22-inch cylinders with drainage outlets in cylinders. 13 miles per hour.

M. P. 394 A—Sixth Sheet
8 x 10½

[illegible]

Pennsylvania Railroad Company

Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company

TEST DEPARTMENT

Average Results of Locomotive Tests

LOCOMOTIVE:
TYPE 2–8–0
CLASS H6b
NUMBER 2860

Bulletin No. 13

FUEL: Jamison Coal

SUBJECT: Cylinder Drained.

ALTOONA, PA., 6–8–1909

Test Number	Running Conditions: Test Designation	Duration of Test, Hours	Miles per Hour	Throttle Opening, Full or Partial	Actual Cut-off Per Cent., H. P. Cylinders	Size of Orifice	Boiler Performance: Pressure in Boiler, Lbs. per Sq. Inch	Draft in Smoke Box, Inches of Water	Draft in Ash Pan, Inches of Water	Calorific Value of Dry Fuel, B. T. U. per Lb.	Cinders Collected in Smoke Box, Pounds per Hour
	R. P. M. Cut-off Throttle	196	199	203	268 to 271		217	222	225	248	238
1200.312	100–45–F	0.5	16.25	Full	45.0	1/32 in.	204.5	5.4	0.2		
1200.313	100–45–F	0.5	16.25	"	45.1	1/16 "	203.8	5.7	0.2		
1200.314	100–45–F	0.5	16.25	"	45.1	1/8 "	201.3	5.7	0.2		
1200.315	100–45–F	0.5	16.25	"	45.4	3/16 "	202.0	5.4	0.2		
1200.316	100–45–F	0.5	16.25	"	44.6	1/4 "	198.0	5.3	0.2		
1200.317	100–45–F	0.5	16.25	"	45.0	5/16 "	193.3	5.0	0.2		

Test Number	Boiler Performance: Dry Fuel Fired per Hour, Pounds	Dry Fuel per Hour, Pounds per Sq. Ft. of Grate	Water Delivered to Boiler, Pounds per Hour	Equivalent Evaporation from and at 212° F., Pounds: Per Hour	Per Hour per Sq. Ft. of Fire Heating Sur.	Per Pound of Dry Fuel	Boiler Horse Power (34½ U. of E.)	Efficiency of Boiler, Based on Fuel		Engine Performance: Pressure in Branch Pipe, Pounds per Sq. In.	Superheat in Branch Pipe Degrees F.
	338	339	340	344	345	347	349	350		220	230
1200.312			31772	38165	15.23		1106.3				
1200.313			31492	37801	15.12		1098.0				
1200.314			31442	37827	15.10		1095.6				
1200.315			31312	37707	15.05		1093.0				
1200.316			30602	36838	14.70		1067.8				
1200.317			30108	36225	14.46		1050.0				

Test Number	Engine Performance: Dry Steam to Engines, Pounds per Hour	Indicated Horse Power	Dry Fuel per Indicated Horse Power Hour, Pounds	Dry Steam per Indicated Horse Power Hour, Pounds		Locomotive Performance: Drawbar Pull, Pounds	Dynamometer or Drawbar Horse Power	Dry Fuel per Dynamom. Horse Power Hour, Pounds	Dry Steam per Dynamom. Horse Power Hour, Pounds	Machine Efficiency of Locomotive, Per Cent.	Thermal Efficiency of Locomotive, per Cent., (Based on Fuel)	
	214	379	380	381		265	383	384	385	398	399	
1200.312	31306	1259.1		24.86		25638	1110.9		28.18	88.2		
1200.313	31089	1259.8		24.68		25801	1118.0		27.81	88.7		
1200.314	31006	1256.4		24.68		25637	1110.9		27.91	88.4		
1200.315	30933	1245.9		24.83		25537	1106.5		27.96	88.8		
1200.316	30232	1226.6		24.65		25336	1097.8		27.54	89.5		
1200.317	29744	1191.9		24.96		24735	1071.8		27.75	89.9		

Table XI.

H6b locomotive, 22-inch cylinders with drainage outlets. 16 miles per hour.

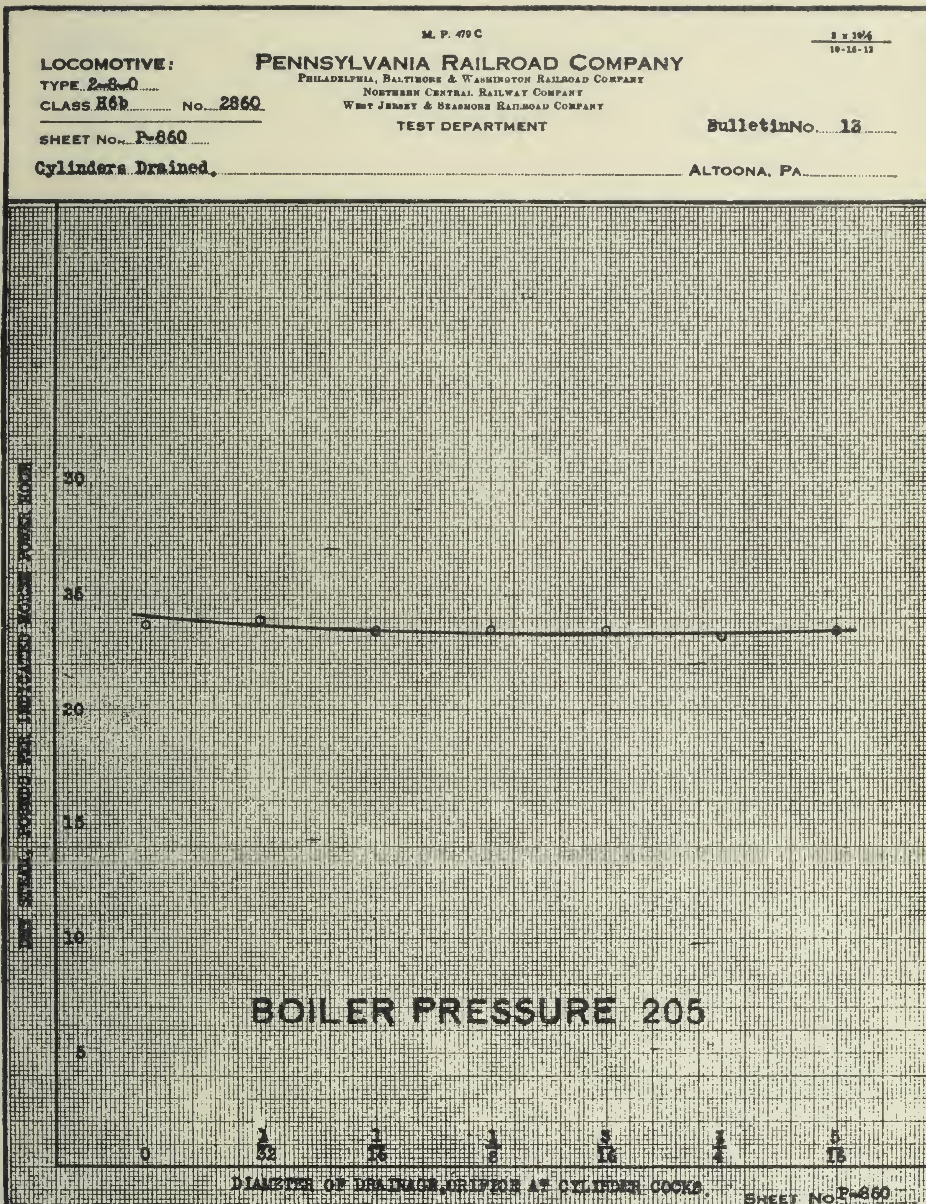


Fig. 31.

CYLINDERS DRAINED.

Speed 13 m.p.h., Cut-off 30 per cent. The steam rate decreases as the outlet is enlarged up to $\frac{1}{8}$ inch.

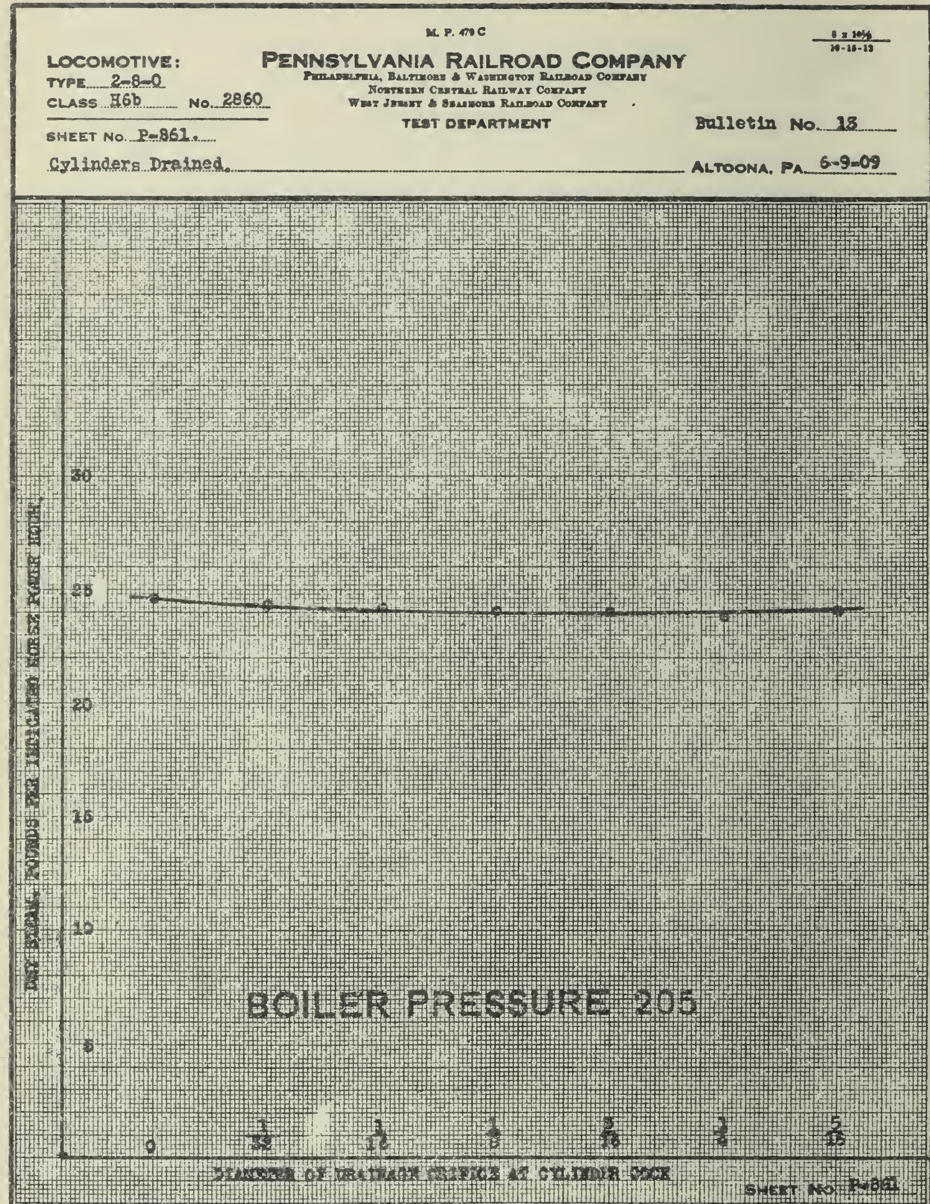


Fig. 32.

CYLINDERS DRAINED.

Speed 13 m.p.h., cut-off 40 per cent. Tests at a longer cut-off than in Fig. 31.

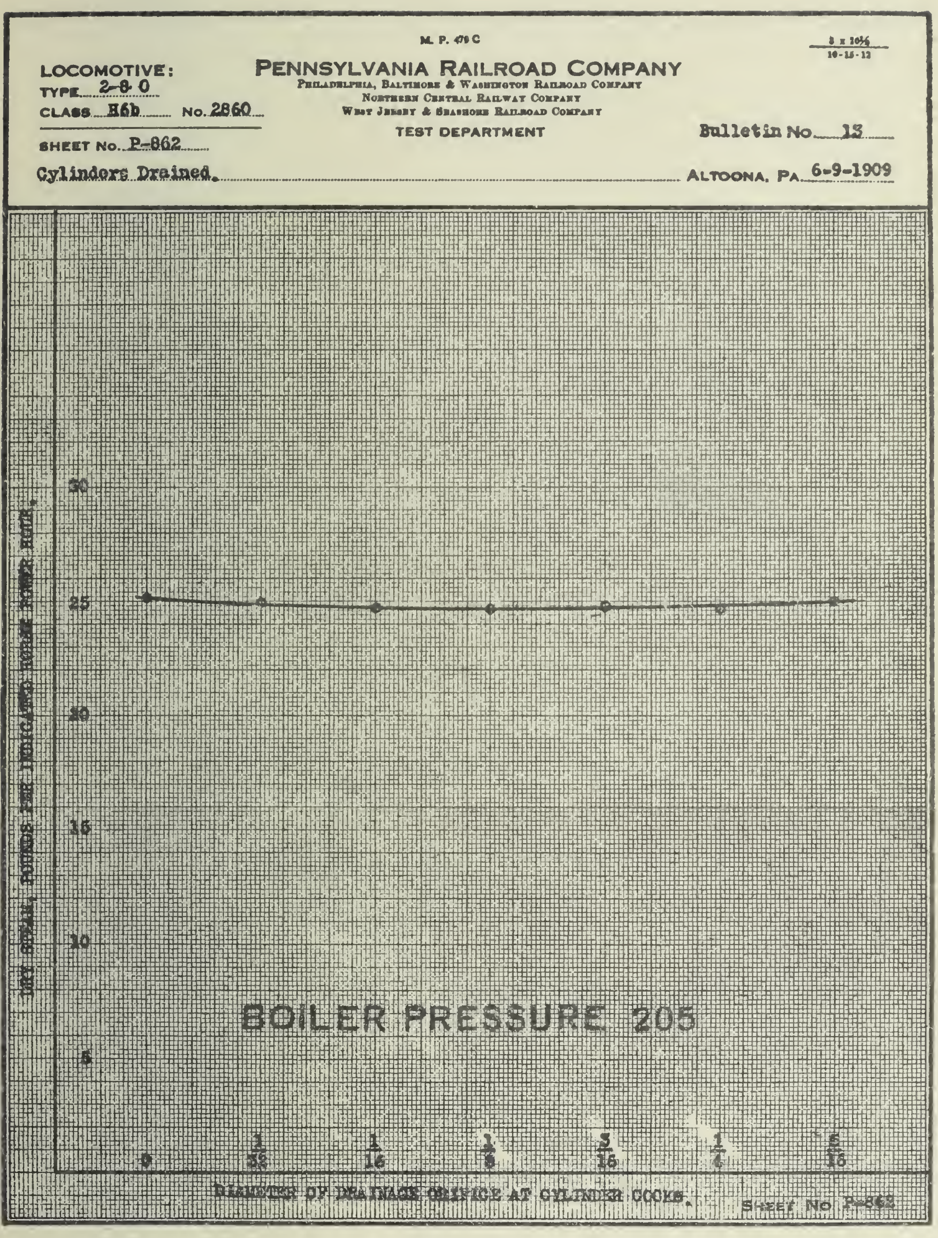


Fig. 33.

CYLINDERS DRAINED.

Speed 16 m. p. h., cut-off 45 per cent. Tests at a higher speed than in Figs. 31 and 32.

M. P. 894A
8 x 10½

7 6 1907

Pennsylvania Railroad Company

Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company

TEST DEPARTMENT

Average Results of Locomotive Tests

LOCOMOTIVE:
TYPE 2-8-0
CLASS H6b
NUMBER 2846

Bulletin No. 13
TEST NOS., 1301 to 1331

SUBJECT: Smokebox Superheater

ALTOONA, PA., 3-31-1909

	Driving Wheels	
1	Number of Pairs	4
2	Approx. Diameter, inches	56
	Engine Truck Wheels	
14	Number	2
15	Diameter, inches	30
	Trailing Wheels	
16	Diameter, inches	-
	Wheel Base, Feet	
17	Driving Wheel Base	16.25
18	Total Wheel Base	24.84
19	Gage of Wheels	4.75
	Weight of Engine with Water at 2d. Gage Cock and Normal Fire, Pounds	
20	On Truck	-
21	" 1st Drivers	-
22	" 2d "	-
23	" 3d "	-
24	" 4th "	-
25	" 5th "	-
26	" Trailers	-
27	Total	-
28	" on Drivers	-
	Cylinders	
	Diam. and Stroke, H. P.	25 x 28
	" " " L. P.	-
	Clearance in per cent. of Piston Displacement	
40	H. P. Right, Head End	10
41	" " Crank "	11
42	" Left, Head "	12
43	" " Crank "	11
44	L. P. Right, Head "	-
45	" " Crank "	-
46	" Left, Head "	-
47	" " Crank "	-
	Receiver, Cubic Feet	
48	Volume Right Side	-
49	" Left "	-
	Steam Ports, Inches	
50	H. P. Admission, Length	-
51	" " Width	2
58	L. P. " Length	-
59	" " Width	-
66	H. P. Exhaust, Length	No Port
67	" " Width	" "
70	L. P. " Length	-
71	" " Width	-

	Piston Rods, Diameter Inches	
74	High Pressure	3.95
76	Low "	-
	Tail Rods, Diameter, Inches	
78	High Pressure	-
80	Low "	-
	Valves	
82	Type	Piston
83	Design	Amer. Bal. Valve Co.
84	Per Cent. Balanced	100
85	Type of Valve Motion	Walscherts
	Greatest Valve Travel	
86	High Pressure, inches	5.75
88	Low " "	-
	Steam Lap of Valve	
90	High Pressure, inches	.86
94	Low " "	-
	Exhaust Lap of Valve	
98	High Pressure, inches	.06
102	Low " "	-
	Boiler	
113	Type	Belpaire, Wide Firebox
114	Outside Diam. 1st Ring	71
	Tubes	
115	Number	373
116	Outside Diam., inches	2
	Pitch "	2.69
118	Length Between Tube Sheets, inches	164.3
119	Total Fire Area, sq. ft.	6.2
124	Boiler Pressure, pounds	160
	Superheater	
125	Number of Tubes	336
126	Outside Diam. " inches	1.25
128	Length of " "	Avg. 42.4
	Firebox, Inside, Inches	
132	Length	118.3
133	Width	65.0
137	Air Inlets to Ashpan, sq. ft.	11.4
	Grates	
144	Type	Rocking Finger
145	Grate Area, sq. ft.	48.7
146	Area of Dead Grates	0

	Heating Surface, Square Feet	
154	Of the Tubes, Water Side	2673.7
155	" " " Fire "	2339.2
156	" " Firebox, " "	166.1
157	" " Superh'r, " "	389.0
*158	Total, Based on " "	2505.3
159	" " " " " of Firebox and Water Side of Tubes	2839.7
	Boiler Volume with Water Surface at Level of 2d Gage Cock	
160	Water Space, cu. ft.	350
161	Steam " " "	81
	Exhaust Nozzle	
162	Double or Single	Single
163	Size, inches	5.625
167	Area, sq. inches	24.85
	Reverse Lever	
168	H. P. Notches Forward of Center	22
169	L. P. Notches Forward of Center	-
	Ratios	
171	Heating Surface (158) to Grate Area (145)	51.5'
172	Fire Area Thru Tubes (119) to Grate Area (145)	.1
173	Firebox Heating Surface (156) to Grate Area (145)	3.4
174	Tube Heating Surface (155) to Fire Box Heating Surface (156)	14.1

*USED IN CALCULATIONS

Table XII.
Dimensions of superheater locomotive 2846.

GRAPHICAL LOGS OF TESTS.

A graphical log is made for each test to show the condition at each ten-minute interval, and to indicate any irregularity in the weights of coal and water during the run. These diagrams are on file with the Test Plant records. A few representative ones only being shown here.

M. P. Experimental D-1

13 9 1911 / 8 x 10½

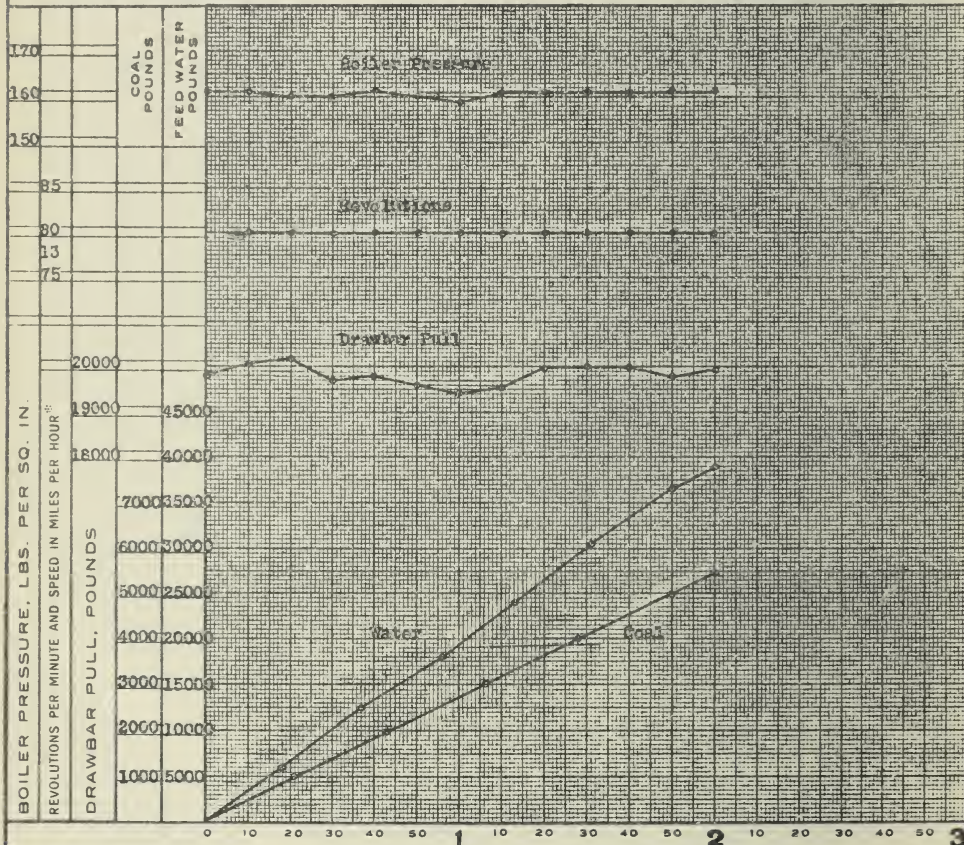
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-863 TEST DEPARTMENT Bulletin No. 13

GRAPHICAL LOG OF LOCOMOTIVE TEST

Smokebox Superheater ALTOONA, PA., 3-23-1909



LENGTH OF TEST—MINUTES AND HOURS

* UPPER FIGURES R. P. M.
LOWER FIGURES APPROX.
SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 2-8-0
CLASS H6b
NUMBER 2846

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
13.34	80	40	F	7.1

TEST NO. 1302

SHEET NO. P-863

M. P. Experimental D-1

13 ₮ 1911
R x 10½

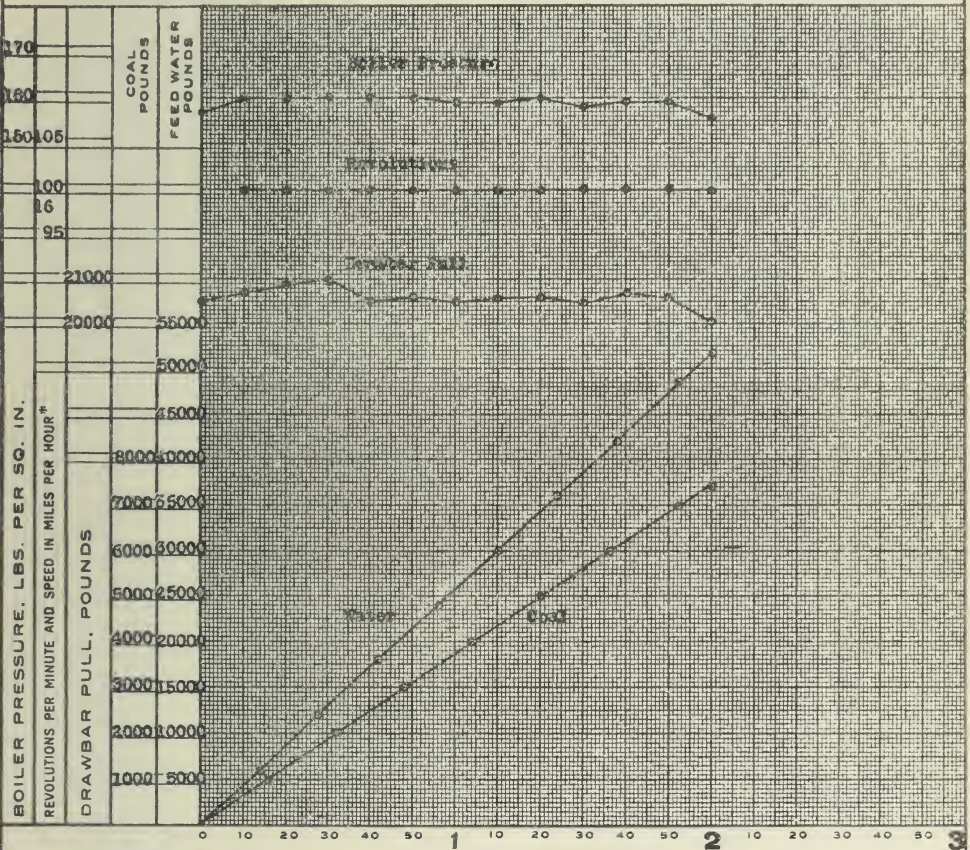
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-864 TEST DEPARTMENT Bulletin NO 13

GRAPHICAL LOG OF LOCOMOTIVE TEST

Smokebox Superheater ALTOONA, PA., 3-24-1912



LENGTH OF TEST—MINUTES AND HOURS

*UPPER FIGURES R. P. M.
LOWER FIGURES APPROX.
SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 2-8-0
CLASS H6b
NUMBER 2846

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
16.67	100	45	F	7.02

TEST NO. 1303

SHEET NO. P-864

M. P. Experimental D-1

12 9 1911
8 x 1916

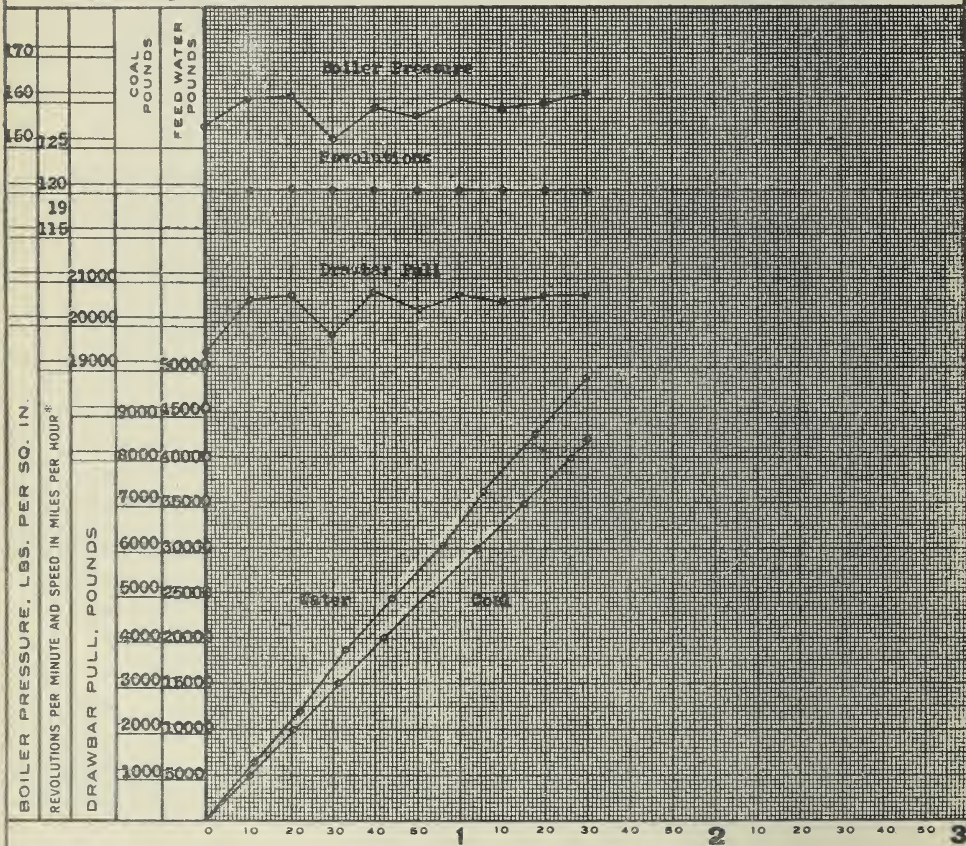
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-865 TEST DEPARTMENT Bulletin NO. 13

GRAPHICAL LOG OF LOCOMOTIVE TEST

Smokebox Superheater ALTOONA, PA. 5-24-1913



LENGTH OF TEST—MINUTES AND HOURS

*UPPER FIGURES R. P. M
LOWER FIGURES APPROX.
SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 2-8-0
CLASS H6b
NUMBER 2846

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., K. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
20.00	120	50	F	5.82

TEST NO. 1306

SHEET NO. P-865

M. P. Experimental D-1

12 9 1911
R z 10½

PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-866

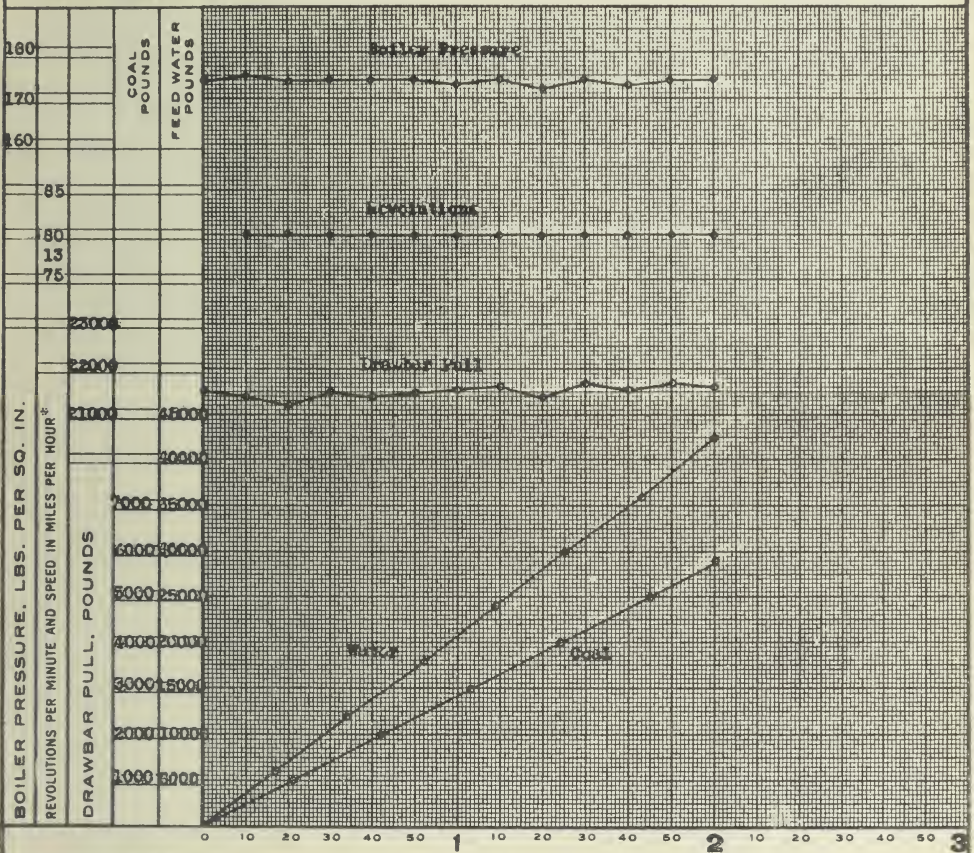
TEST DEPARTMENT

Bulletin No. 13

GRAPHICAL LOG OF LOCOMOTIVE TEST

Smokebox Superheater

ALTOONA, PA., 3-30-1909



*UPPER FIGURES R. P. M.
LOWER FIGURES APPROX.
SPEED IN MILES PER HOUR

LENGTH OF TEST—MINUTES AND HOURS

LOCOMOTIVE
TYPE 2-8-0
CLASS H6b
NUMBER 2846

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
13.34	80	40	F	7.7

TEST NO. 1308

SHEET NO. P-866

M. P. Experimental D-1

12 9 1911
8 x 10½

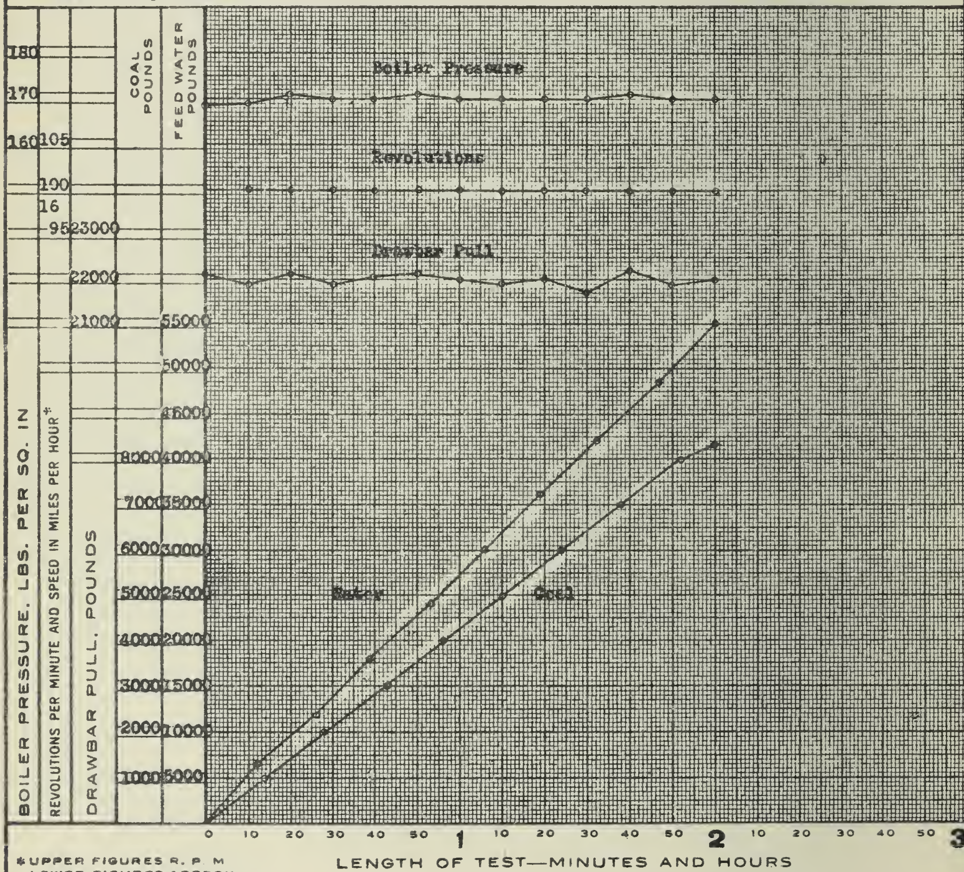
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-867 TEST DEPARTMENT Bulletin NO. 13

GRAPHICAL LOG OF LOCOMOTIVE TEST

Smokebox Superheater ALTOONA, PA. 3-30-1909



*UPPER FIGURES R. P. M
LOWER FIGURES APPROX.
SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 2-8-0
CLASS H6b
NUMBER 2846

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
16.67	100	45	F	6.6

TEST NO. 1309

SHEET NO. P-867

M. P. Experimental D-1

13 9 1911
8 x 10½

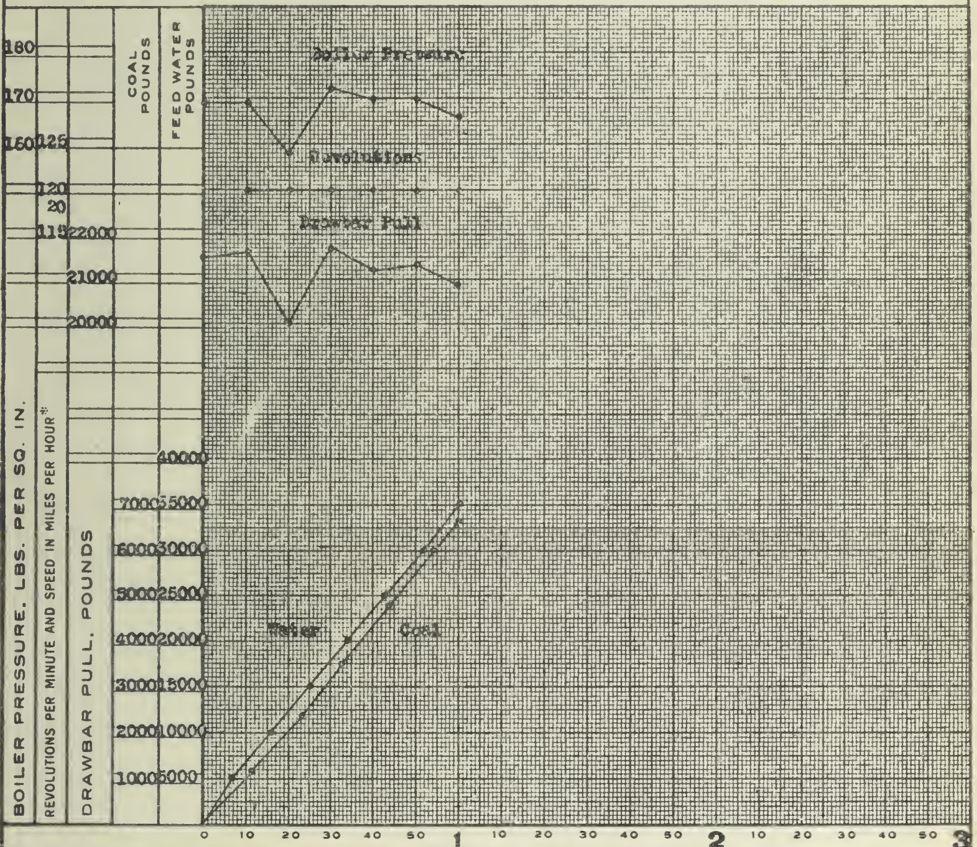
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-868 | TEST DEPARTMENT | Bulletin NO 13

GRAPHICAL LOG OF LOCOMOTIVE TEST

Smokebox Superheater | ALTOONA, PA., 3-31-1909



LENGTH OF TEST—MINUTES AND HOURS

*UPPER FIGURES R. P. M.
LOWER FIGURES APPROX.
SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 2-8-0
CLASS H6b
NUMBER 2846

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
20	120	50	F	4.71

TEST NO. 1311

SHEET NO. P-868

M. P. Experimental D-1

12 9 1911
8 x 10½

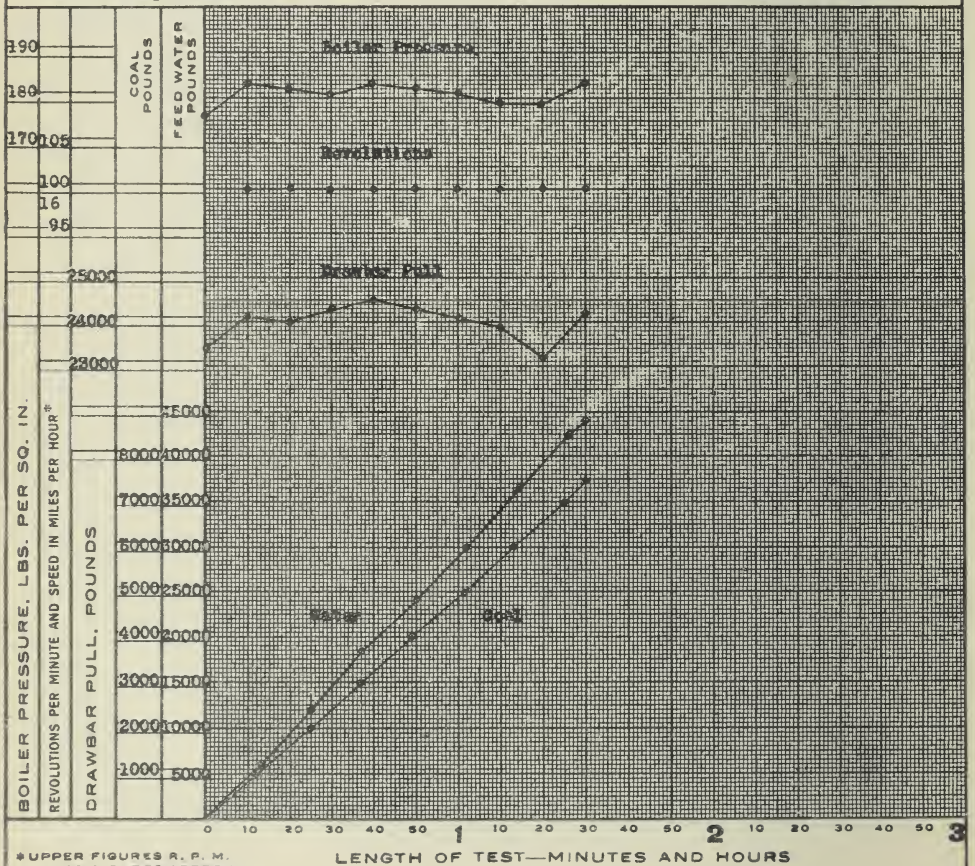
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-869 TEST DEPARTMENT Bulletin NO. 13

GRAPHICAL LOG OF LOCOMOTIVE TEST

Smokebox Superheater ALTOONA, PA., 4-2-1909



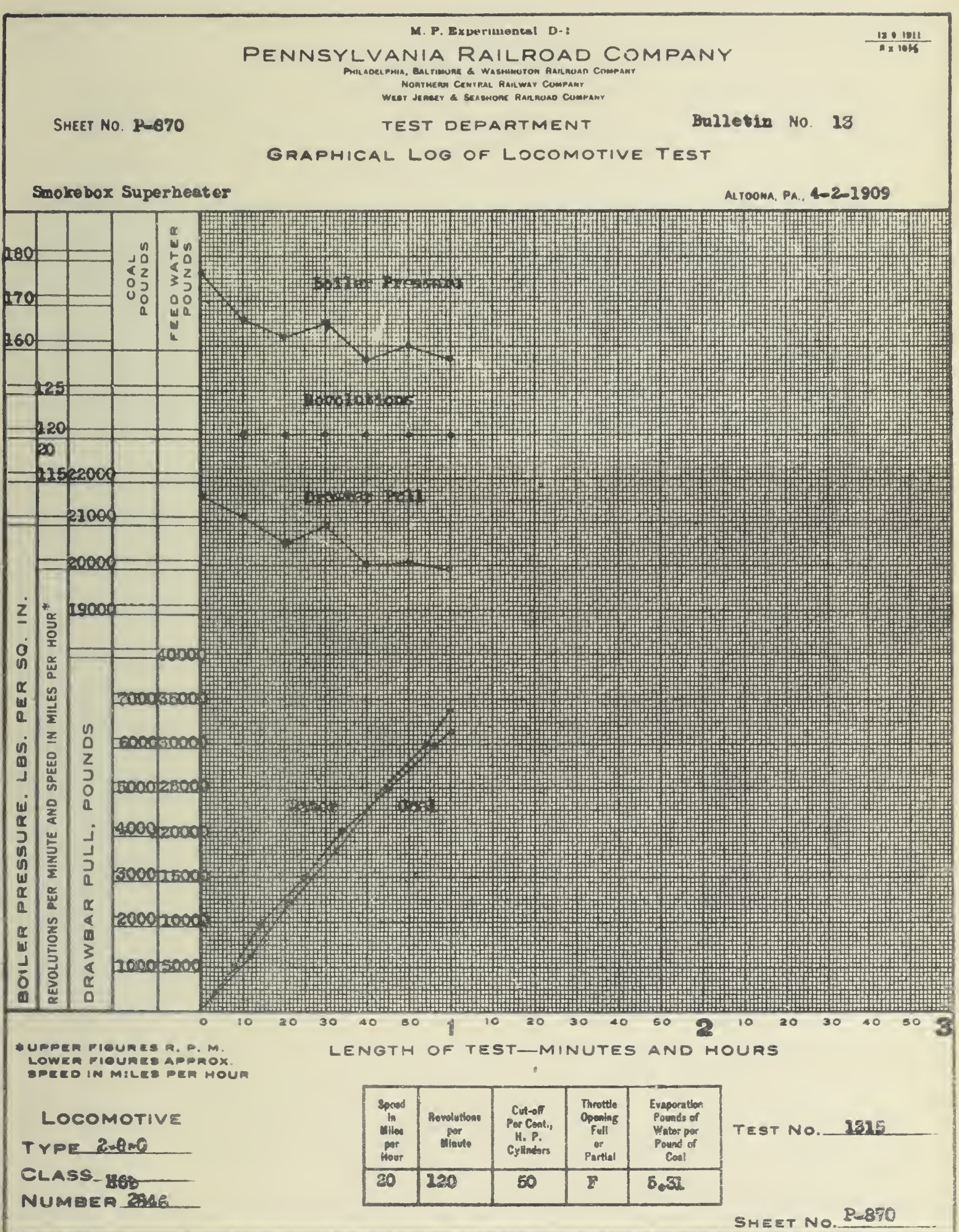
*UPPER FIGURES R. P. M.
LOWER FIGURES APPROX. SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 2-8-0
CLASS H6b
NUMBER 2846

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
16.67	100	45	F	5.86

TEST NO. 1314

SHEET NO. P-869


M. P. Experimental D-1
PENNSYLVANIA RAILROAD COMPANY
PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY
SHEET NO. P-870
TEST DEPARTMENT
Bulletin No. 13
GRAPHICAL LOG OF LOCOMOTIVE TEST
Smokebox Superheater
ALTOONA, PA., 4-2-1909
Boiler Pressure
Revolutions
Drawbar Pull
COAL POUNDS
FEED WATER POUNDS
BOILER PRESSURE, LBS. PER SQ. IN.
REVOLUTIONS PER MINUTE AND SPEED IN MILES PER HOUR*
DRAWBAR PULL, POUNDS
LENGTH OF TEST—MINUTES AND HOURS
*UPPER FIGURES R. P. M.
LOWER FIGURES APPROX.
SPEED IN MILES PER HOUR
LOCOMOTIVE
TYPE 2-8-0
CLASS H6b
NUMBER 2846
Speed in Miles per Hour
Revolutions per Minute
Cut-off Per Cent., H. P. Cylinders
Throttle Opening Full or Partial
Evaporation Pounds of Water per Pound of Coal
20
120
50
F
5.31
TEST NO. 1315
SHEET NO. P-870

M. P. Experimental D-1

12 9 1911
3 x 10½

PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-871

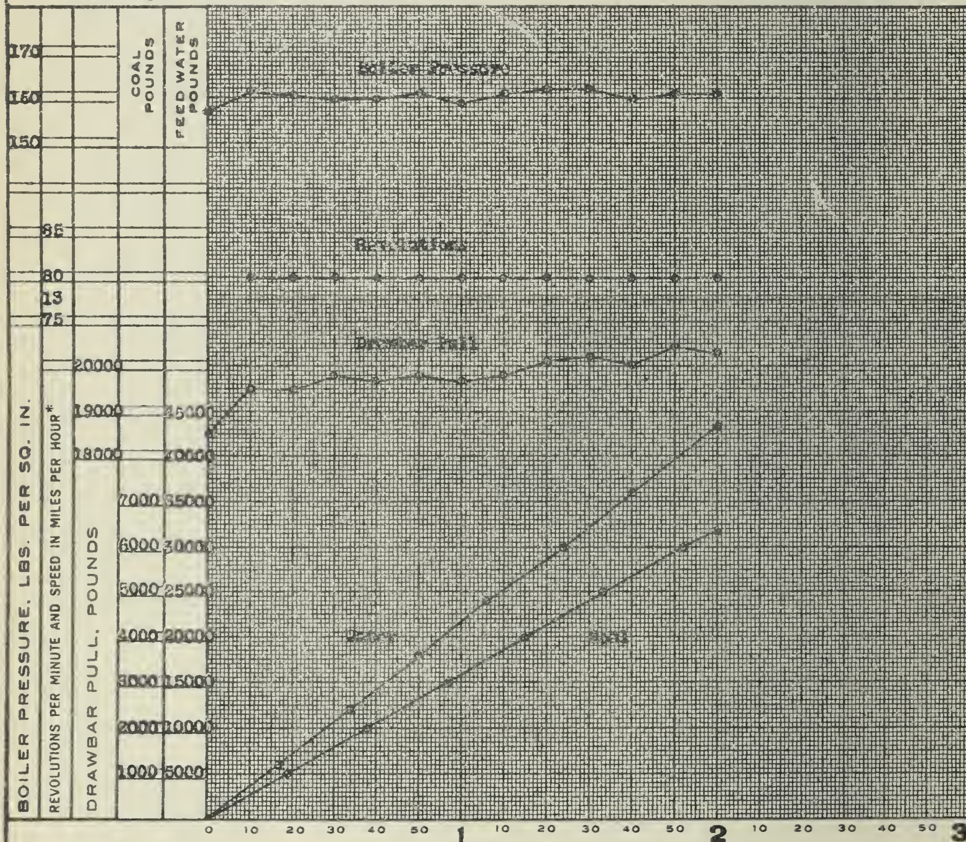
TEST DEPARTMENT

Bulletin NO. 13

GRAPHICAL LOG OF LOCOMOTIVE TEST

Smokebox Superheater - Superheater Removed

ALTOONA, PA., 4-5-1909



LENGTH OF TEST—MINUTES AND HOURS

*UPPER FIGURES R. P. M.
LOWER FIGURES APPROX.
SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 2-8-0
CLASS H6b
NUMBER 2846

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
13.34	80	40	F	6.8

TEST NO. 1318

SHEET NO. P-871

M. P. Experimental D-1

13 8 1911
8 x 10½

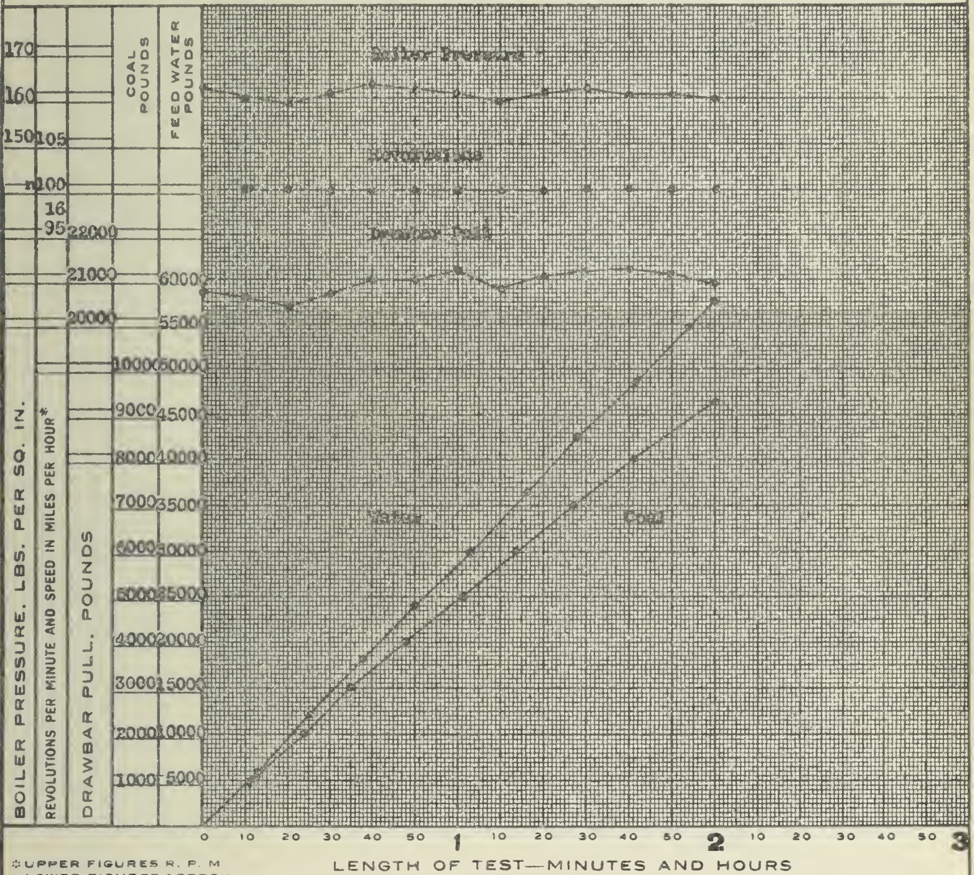
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-872 TEST DEPARTMENT Bulletin No. 13

GRAPHICAL LOG OF LOCOMOTIVE TEST

Smokebox Superheater - Superheater Removed ALTOONA, PA., 4-8-1909



*UPPER FIGURES R. P. M
LOWER FIGURES APPROX.
SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 2-8-0
CLASS H6b
NUMBER 2846

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
16.67	100	45	F	6.18

TEST NO. 1319

SHEET NO. P-872

M. P. Experimental D-1

12 9 1911
8 x 10½

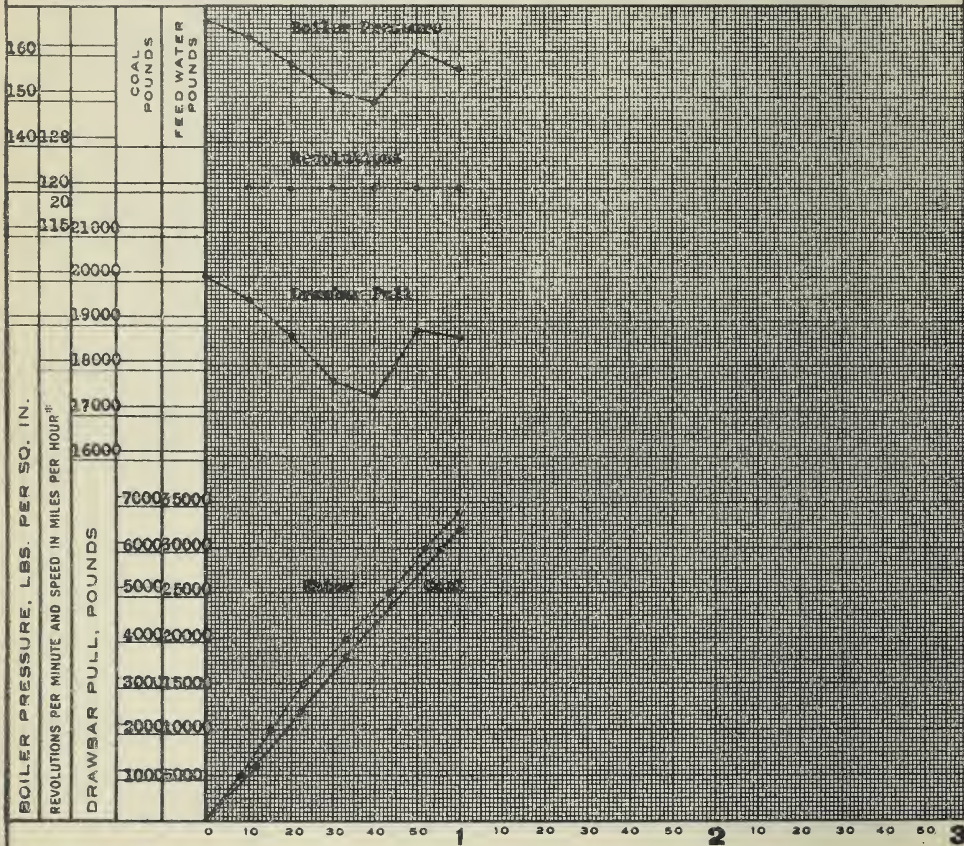
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-873 TEST DEPARTMENT Bulletin No. 13

GRAPHICAL LOG OF LOCOMOTIVE TEST

Smokebox Superheater - Superheater Removed ALTOONA, PA., 4-8-1909



LENGTH OF TEST—MINUTES AND HOURS

*UPPER FIGURES R. P. M.
LOWER FIGURES APPROX.
SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 2-8-0
CLASS H6b
NUMBER 2346

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
20	120	50	F	4.70

TEST NO. 1320

SHEET NO. P-873

M. P. Experimental D-1

12 9 1913 / 9 x 10½

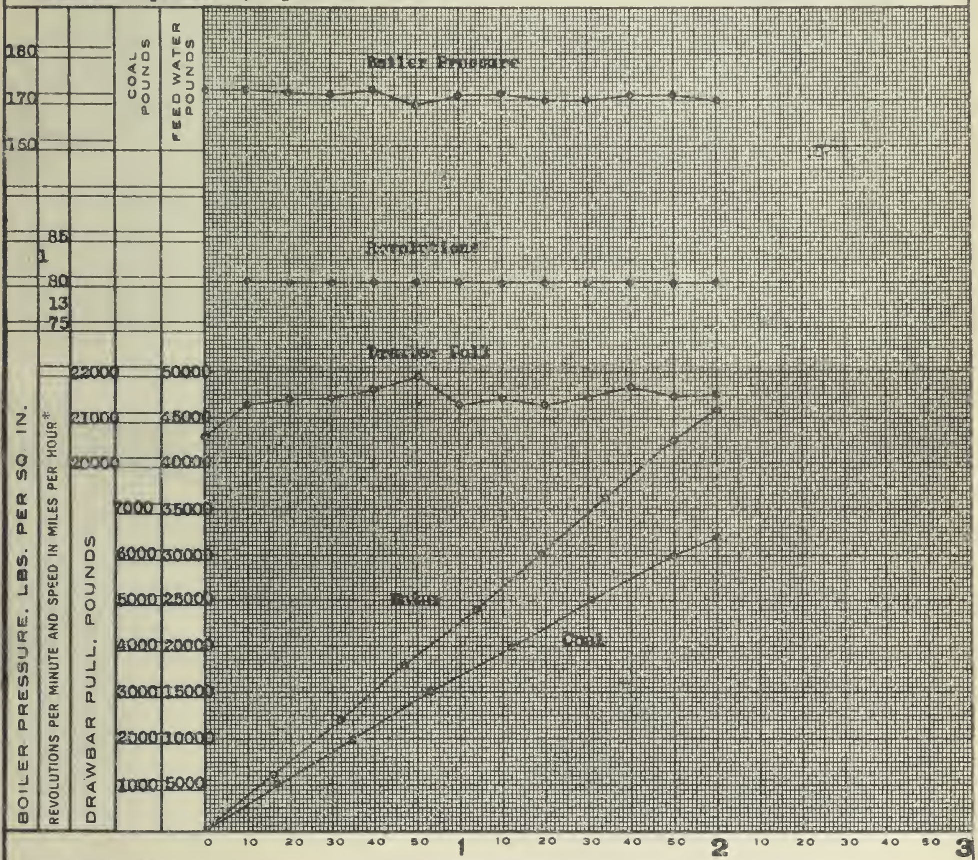
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-874 TEST DEPARTMENT Bulletin No. 13

GRAPHICAL LOG OF LOCOMOTIVE TEST

Smokebox Superheater, Superheater Removed ALTOONA, PA., 4-12-1909



*UPPER FIGURES R. P. M.
LOWER FIGURES APPROX.
SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 2-8-0
CLASS H6b
NUMBER 2846

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
13.24	80	40	F	7.2

TEST NO. 1322

SHEET NO. P-874

M. P. Experimental D-1

12 9 1911
6 x 10½

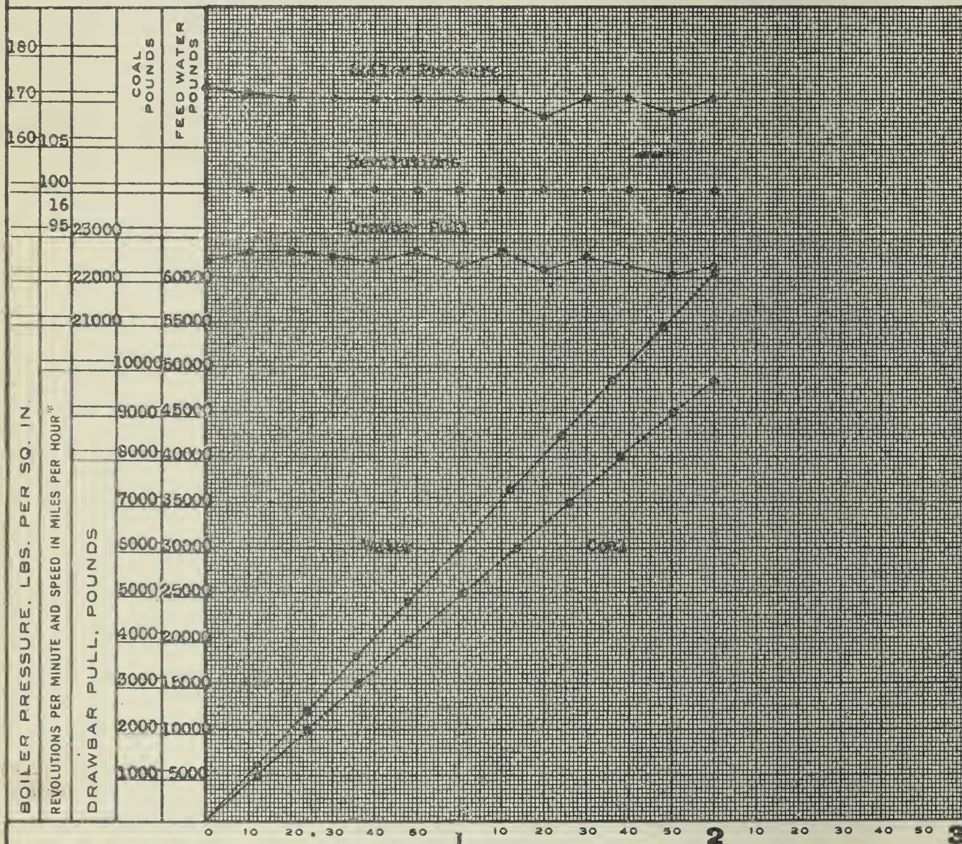
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-875 TEST DEPARTMENT Bulletin NO. 13

GRAPHICAL LOG OF LOCOMOTIVE TEST

Smokebox Superheater, Superheater Removed ALTOONA, PA., 4-13-1912



LENGTH OF TEST—MINUTES AND HOURS

*UPPER FIGURES R. P. M.
LOWER FIGURES APPROX.
SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 2-8-0
CLASS H6b
NUMBER 2846

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
16.67	100	45	F	6.24

TEST NO. 1323

SHEET NO. P-875

M. P. Experimental D-1

12 6 1911
8 x 10½

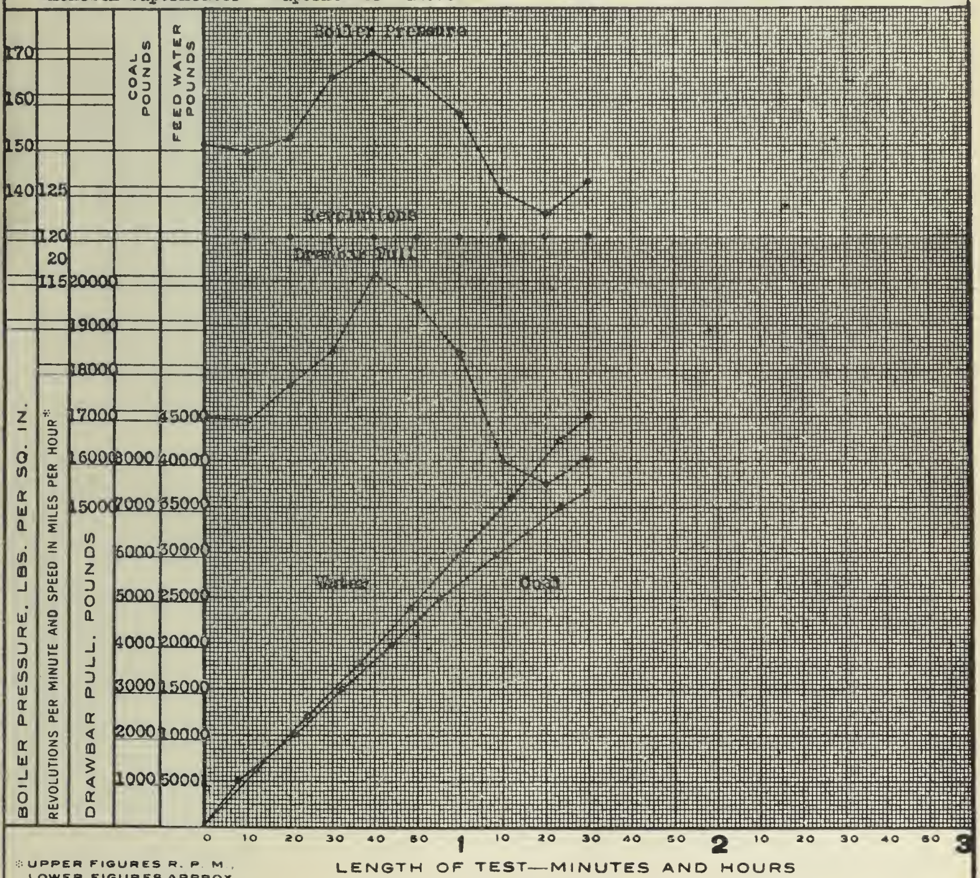
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-876 TEST DEPARTMENT Bulletin NO. 13

GRAPHICAL LOG OF LOCOMOTIVE TEST

Smokebox Superheater – Superheater Removed ALTOONA, PA. 4-13-1909



* UPPER FIGURES R. P. M., LOWER FIGURES APPROX. SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 2-8-0
CLASS H6b
NUMBER 2846

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
20	120	45	F	6.08

TEST NO. 1324

SHEET NO. P-876

M. P. Experimental D-1

12 5 1912
8 x 10½

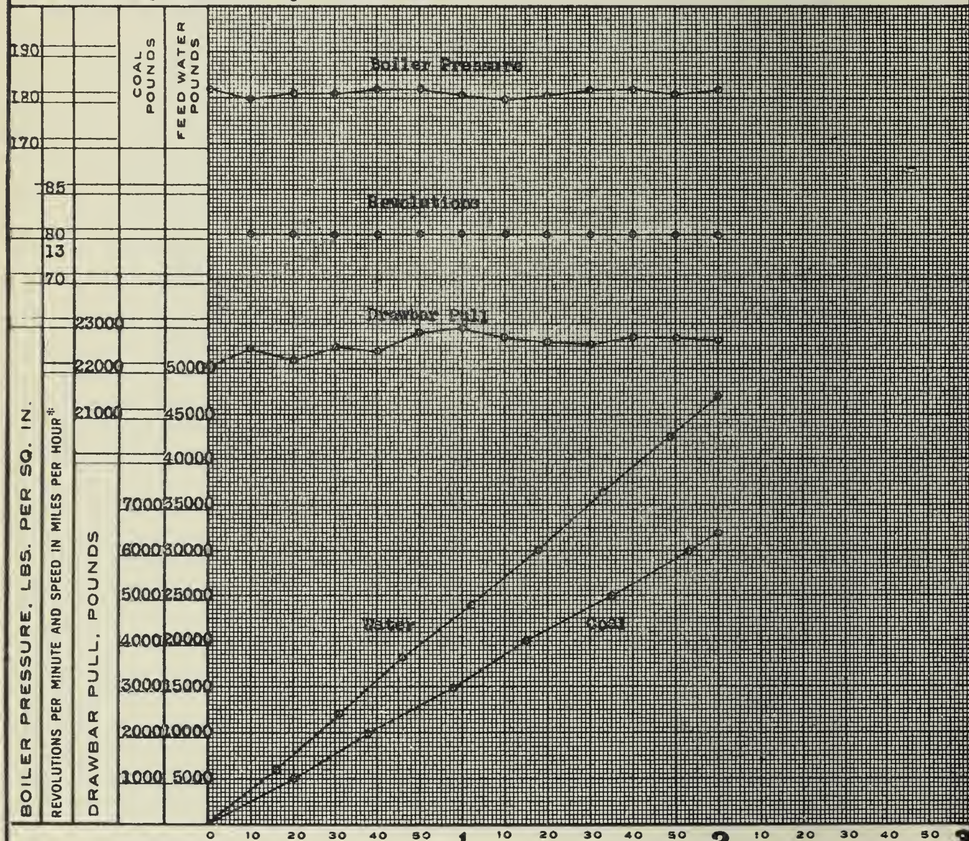
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-877 TEST DEPARTMENT Bulletin No. 13

GRAPHICAL LOG OF LOCOMOTIVE TEST

Smokebox Superheater - Superheater Removed ALTOONA, PA., 4-16-1909



LENGTH OF TEST—MINUTES AND HOURS

*UPPER FIGURES R. P. M.
LOWER FIGURES APPROX.
SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 2-8-0
CLASS H6b
NUMBER 2846

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
13.34	80	40	F	7.3

TEST NO. 1330

SHEET NO. P-877

M. P. Experimental D-1

12 @ 1911
8 x 10½

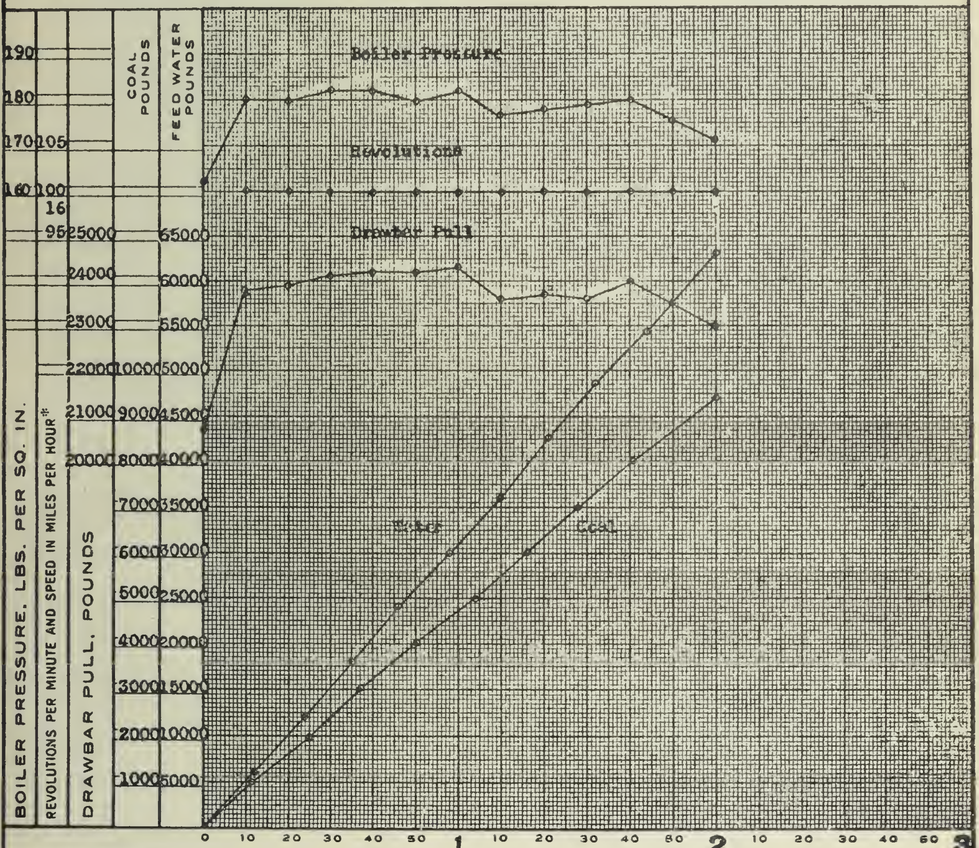
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-878 TEST DEPARTMENT Bulletin No. 13

GRAPHICAL LOG OF LOCOMOTIVE TEST

Smokebox Superheater - Superheater Removed ALTOONA, PA., 4-17-1912



*UPPER FIGURES R. P. M.
LOWER FIGURES APPROX.
SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 2-8-0
CLASS H6b
NUMBER 2846

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
16.67	100	45	P	6.70

TEST NO. 1331

SHEET NO. P-878